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GREENHOUSE GAS EMISSIONS FROM SASKATCHEWAN AGRICULTURE AND POLICY OPTIONS FOR ABATEMENT

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Summary Report to the Agricultural Development Fund

The Centre for Studies in Agriculture, Law and the Environment
(CSALE)

College of Agriculture
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The purpose of this report is to summarise and discuss recent work, current studies and key contacts related to Greenhouse Gas research in Canada. This will make it easier for stakeholders to identify concerns, issues and opportunities associated with such research for the Prairies and Canada.

The summary report is divided into 4 sections:

Section I: Executive summary
Section II: Recommendations
Section III: key players
Section IV: GHG research and Policy Options

A further more complete report has also been submitted and form an integral part of the complete reports presented to ADF.

SECTION I

EXECUTIVE SUMMARY

1 Introduction

The purpose of this report is to summarise and discuss recent work, current studies and key contacts related to Greenhouse Gas research in Canada. This will make it easier for stakeholders to identify concerns, issues and opportunities associated with such research for the Prairies and Canada.

Climate change is recognized as being both a federal and a provincial problem. As a provincial responsibility, it is necessary for Saskatchewan to participate actively in the decision-making process both at the federal and international levels.

Climate change is here to stay and those groups that have the power to influence the course of action must consider this issue of crucial importance. Decisions related to the agricultural sector made by Canada's negotiators at the various international meetings may have an effect on the well-being of farmers in this province for many years to come.

Saskatchewan is a relatively minor player on the federal scene. Hence it is recommended that a process be undertaken to have Saskatchewan and Saskatchewan agriculture represented in a more formal way at the international negotiations. Agriculture needs to have greater say in the policy decisions made by Canada's negotiators or else it may well turn out to be an easy target for a compromise that may have a negative impact on the welfare of our farming community and on the Province's economy as a whole.

2 Climate Change

2.1 Greenhouse Gases

Greenhouse Gases (GHGs) trap the sun's heat near the earth's surface, warming the surface of the earth. Without the greenhouse effect, the earth's average temperature would be -18°C instead of 15°C. An increase in GHG emissions disturbs the natural balance and causes climate change, which provides a significant risk for the global environment and the human economy.

Anthropogenic emissions refer to the release of GHGs into the atmosphere as a result of human activity. Canada contributes 1.8% of net global anthropogenic GHG emissions, 80% of which is carbon dioxide (CO_2) emissions. Canada is the second highest per capita producer of GHG emissions among major industrialised nations. This is generally due to the extreme nature of the climate and large distances between population centres. Our reliance on heating and transportation carries an accompanying increase in energy consumption.

The agriculture sector accounts for only 4% of national CO_2 emissions. Agricultural practices, chemical processes, and fertiliser production and consumption contribute more to methane and nitrous oxide emissions.

- Nitrous oxide (N_20) accounts for 5% of Canada's emissions[1]; 60% is from agriculture
- Methane (CH_4) accounts for 25% Canada's emissions; 13% is from agriculture

Climate change impacts are the effects that are felt as a result of changes in the timing, conditions, frequency and magnitude of weather such as droughts, blizzards and tornadoes. Canada is an area likely to be detrimentally affected by climate change, with some models predicting an increase in temperatures from 2°C to 4°C in the southern part of the country and even higher further north. Some possible impacts for Canada include:

Threats to human habitat. Increased global temperatures may melt glaciers, raise sea levels, change rainfall and alter local climate conditions. The changing regional climates could limit forests and water supplies.

Increases in intense events. Major changes may occur in atmospheric circulation and the hydrological cycle, including increased evaporation, humidity and rainfall. Altered atmospheric circulation could affect storm tracks and rainfall distribution. Thunderstorms and related hailstorms and tornadoes are expected to become more frequent and severe as warmer surface temperatures cause air to rise into the atmosphere rapidly (convection). This could also augment the number of intense winter storms, although the total number of storms may decrease.

Dry Spells. With a larger percentage of rain falling as intense events, the duration of dry periods between such events is likely to increase. Coupled with warmer temperature, this suggests an increase in drought frequency and severity, particularly as defined by soil moisture. The frequency, duration and severity of extreme heat spells may lead to more extensive and damaging forest fires.

Changes in Crop Yields. An initial increase in temperature could be positive for crop yields. The extent of the response may vary from crop to crop and can change from positive to negative if the temperature change is strong enough. New combinations of climate,

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[1] Measured on a CO_2 equivalent basis

atmospheric constituents, and soil conditions may lead to crop losses due to weeds, insects, and disease.

Regional shifts in production. Farmland in the southern regions of the country may experience drought, possibly reducing crop yields and increasing demand for irrigation. Longer and warmer growing seasons could produce higher yield crops where soil moisture levels are adequate and agriculture could expand further north wherever soil quality is suitable.

2.2 The Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change was adopted at the third session of the Conference of the Parties (COP-3) in December 1997. If ratified, it contains legally binding emissions targets for Annex I (developed) countries for the post-2000 period. Canada's target is to reduce its GHG emissions to 6 percent below 1990 levels by the 2008-2012 time frame. This target would require an emissions reduction by 2008 - 2012 of approximately 25%, from a "business as usual" scenario.

After signing Kyoto, a considerable amount of funding was provided by the federal government to investigate plans for emission reduction. In the initial stage, Options Papers were developed by expert groups (Tables) to provide a direction for research. From the research that resulted, few reduction options have been implemented because the economic implications of a rapid transition to lower emissions are still unclear[2].

2.3 The Issue Tables

The Agriculture Table reviewed the technologies that showed some verifiable low-cost reduction in GHG emissions. Most involved carbon sinks that are currently not part of the Kyoto Protocol. Increased zero tillage, reduced summerfallow, improved grazing strategies, and conversion of cropland to wetland and wildlife habitats showed promise for net emission reduction as soil sinks. Agroforestry and shelterbelts showed promise as forest sinks. Strawboard and other fibre manufacture showed promise for net emission reduction as industrial sinks.

The Sinks Table suggested that the encouragement of conservation practices on cropland, including no till and reduction in conventional summerfallow – offered the most potential in both the first and second commitment periods. Furthermore, it is potentially one of the more cost-effective strategies. As far as pasture management is concerned, it includes such practices as pasture fertilisation and intensive pasture grazing management. The enhancement of wetlands through the restoration of marginal land around Prairie potholes is also recommended. Agricultural soil sequestration could offer crop producers greater revenue, and potentially lower input costs resulting from lower fuel use, as well as more

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[2] While a link exists between GHG emissions and the growth of the economy (Canada has one of the highest rates of economic growth among the G-7 nations)' Environment Canada has noted that this correlation is not necessarily as direct as recent trends may imply. There have been periods where emissions decreased as the Gross Domestic Product increased (Environment Canada, 1999).

efficient use of fertilisers. The overall impact of agricultural soils conservation practices on the environment is a healthier, more productive soil that is less subject to wind or water erosion, and more sustainable ago ecosystems and environment.

The Forestry Table recommended that plant shelterbelts be created on private land in the Prairies provinces each year from 2001 to 2015 (15 years). The target rate for planting would be 13,000 ha per year. For block plantations on private land in the Prairies provinces a target rate for planting would be 20,000 ha per year.

The Analysis and Modelling Table recommended the coherency of baseline data used in evaluating various measures/options to address climate change[3]. The Table is working on an analytical framework to ensure consistency and comparability of methodologies and approaches in evaluating various measures/options to address climate change and their implications, and directing the "roll-up" analysis and modelling various implementation scenarios built on various combinations of specific measures/options.

The Technology Issues Table examined the advancement of the role of technology to achieve two primary goals:

1. Contribute to the reduction of GHG emissions through development and commercialisation of innovative technologies; and,
2. To enhance capabilities and opportunities for Canadian companies in providing environmentally responsive technologies in domestic and international markets. Both energy and non-energy technologies are included.

2.4 Understanding GHG Emissions Accounting

Environment Canada maintains a National Greenhouse Gas Inventory that has been structured to match the "good practice" requirements of the International Panel on Climate Change (IPCC). It has been divided into six major sectors: Energy; Industrial Processes; Solvents and Other Products; Agriculture; Land Use Change and Forestry; and Waste. The accounting is then further divided into more manageable areas (ex: science, policy, implementation) and subdivided into categories (ex: transportation, agriculture, buildings).

For GHG inventory purposes, agriculture emissions are limited to enteric fermentation of domestic animals, manure management practices, and cropping practices that result in a release from soils.

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[3] Baseline is a term used to refer to the practise that would have taken place irrespective of the Kyoto Protocol. Baseline measures are important because the Protocol only recognizes what is done over and above the normal practice. No till becomes important only if it was something farmers would not have done except as a "new" measure.

While this method minimises duplication, the arbitrary boundaries distort reality. The agriculture industry in the "real world" involves many aspects including land, machinery, chemicals, and transportation. Another more comprehensive approach is to account for all significant emissions related to a project, whether they take place on-site or off-site. In energy analysis, this approach is known as the total fuel cycle or *full energy supply cycle*. Under such " whole system" accounting, the material impacts of activities that relate to the project activity but occur before or after it are taken into account.

Farms and the Whole System Approach. Roger Cohen is an animal scientist with the University of Saskatchewan. His work is based on the firm principle that "the animal is part of the ecosystem". Grazing management is relevant to emission reduction because well-managed pastures can also sequester carbon, and placing cattle on pasture reduces methane emissions. He promotes mixed farming as the most desirable model. Producers wishing to move to animal or mixed farming have access to livestock models that will help plan operations that are economically efficient and conserve emissions.
GrassGro is Roger Cohen's model at the University of Saskatchewan which aims to improve pasture quality and keep ruminants on pasture for as long as possible. It combines soil data and other conditions with information on plant and cattle types to help producers plan their best management practice.

While emission reductions must be within the context of the "good practice guidelines" in order to be recognised under the Kyoto Protocol, the more comprehensive methods must be employed within national emission reduction plans in order for them to be effective. Reduction projects must consider global warming potential to compare the climate change impacts of various gases, the scientific community has developed the concept of Global Warming Potential (GWP), which allows expression of all GHGs on a comparable basis. The strength of all other GHGs is compared to that of carbon dioxide, which is assigned a value of 1. Methane is assumed to be 21 times more powerful than CO_2 in trapping heat, while N_2O is assumed to be 310 times more powerful.

In order for environmental concerns like climate change to be addressed, they must be "translated" into economic terms as a basis for policy decisions. A Canadian System of environmental and resource accounts has been developed to organize physical and monetary statistics related to the environment using classifications, concepts and methods that compatible with Canadian System of National Accounts[4]. The stocks of natural resources, and changes in these stocks due to extraction, discoveries or natural growth, are shown both in physical quantities and in monetary value.

Whole system accounting is necessary for every aspect of emission reduction. Any single option can affect production and emissions in sectors other than the one covered by any particular table. While emissions accounting limits the agriculture sector to processes on the land and emissions from farm animals, changes to agricultural practices may have far-reaching effects. For example, if large amounts of land under cultivation are converted to permanent cover, this will affect the emissions resulting from the transport of grain. Whole-economy analysis takes this a step further, and requires that options be embedded within a model of the North American or global economy, so that import and export quantities, the

4 The source of many of Statistic Canada's economic statistics.

costs of technologies and other factors not determined solely within Canada are taken into account[5].

Many agricultural activities result in emissions of GHGs. The processes that produce emissions are mainly:

1. Enteric fermentation of domestic animals;
2. Manure and fertiliser management practices, and;
3. Cropping practices that result in a release of GHG from the soil;
4. The use of non-renewable energy in agricultural equipment.

Increasing afforestation of agricultural lands and promoting sustainable forest management of such land will help in reducing net GHG emissions. Measures to promote tree planting in rural settings could make an important contribution. The focus in rural forestry would be on increasing afforestation and the building of shelterbelts, or permanent plant coverage with native grasses and incorporating fast growing trees (such as hybrid poplar) in agricultural production.

A number of the changes to farming practices, particularly reduced tilling, decreased use of equipment and fuel consumption. They also offer additional incentives to reduce emissions of GHGs. Beyond the use of energy-efficient practices, there also exist opportunities for manufacturers to develop more energy-efficient agricultural equipment and for farmers to improve other machinery utilisation practices to reduce energy consumption.

The control of methane and nitrous oxide emissions resulting from fertiliser application, conventional tillage practices and cattle production could also have a substantial role in reducing GHG emissions. Methane emissions from ruminants can be reduced through improved feed technologies and increased use of feed additives that improve rumen efficiency. Changing manure-handling practices can reduce the loss of organic carbon to the atmosphere. Finally, actively tailoring fertiliser application practices can reduce emissions of nitrous oxide.

3 Greenhouse Gases In Canada

3.1 Methane

Cattle in Canada produce about 871 000 t of methane annually. Methane production from ruminants is a global phenomenon and the percentage originating in Canada is quite small. It has been estimated that the global production of methane from cattle and sheep has been increasing by about 1% per year, however it is unlikely that abatement will occur. A recent study conducted by Alberta Agriculture, Food and Rural Development concluded methane

[5] Loulou, Kanudia, Labriet, Margolick, and Vaillancourt. Integrated Analysis of Options for GHG Emission Reduction with MARKAL. HALOA Inc. Montreal, March 2000. Pp viii

production is an inescapable consequence of the use of fibre in the production systems for ruminants, and cannot be eliminated without the elimination of ruminant production.

When livestock and poultry manure is stored or treated in systems that promote anaerobic conditions (e.g., as a liquid in lagoons, ponds, tanks, or pits), the decomposition of materials in manure tends to produce methane. When manure is handled as a solid (e.g., in stacks or pits) or deposited on pastures and rangeland, it tends to decompose aerobically and produce little or no methane. A number of other factors related to how the manure is handled also affect the amount of methane produced. Air temperature and moisture affect the amount of methane produced because they influence the growth of the bacteria responsible for methane formation. Soil under anaerobic conditions (wetlands and rice paddies) is a source of CH_4 emissions. Methane production generally increases with rising temperature and residency time. For non-liquid based manure systems, moist conditions (which are a function of rainfall and humidity) favour methane production. Methane emissions from manure management were 4.4 Mt CO_2 equivalent 1996, up from 4 Mt CO_2 in 1990.[6]

J.R. de Freitas is a soil scientist involved in projects investigating what happens to microorganisms in lagoons, including contamination of surrounding areas and nutrient recycling. He notes that the problems of manure management are not as pronounced as in Europe due the aridity of this region. de Freitas stresses that in terms of future research directions, prevention is important. This would require anticipating detrimental effects of poor manure management and being proactive about averting contamination and excess emissions.

All methane research on ruminants, both international and domestic, has concentrated on manipulating dietary content to reduce emissions. For example, Scottish scientists have added the bacterial supplement *brevibacillus parabrevis* to sheep feed and discovered they could cut the amount of methane produced by almost 50%.[7] Similar genetic and nutritional improvements reduced diary cow emissions in the U.S. at the same time milk output increased. However, reports from both the USDA and Alberta Department of Agriculture have suggested that the main way to reduce emissions from beef cattle is to limit production.

3.2 Carbon Dioxide

Carbon dioxide emissions occur as a result of using non-renewable energy and as a direct loss of carbon from agricultural soils. The introduction of no-tillage methods and less summerfallow in many areas of Canada, accompanied by increasing fertiliser application appears to have lessened the loss of organic matter from many soils, and in some provinces agricultural soils have begun to sequester carbon dioxide from the atmosphere[8].

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[6] Canada's Greenhouse Gas Inventory: 1997 Emissions and removals with trends. Pp 47-8.
[7] The Rowett Research Institute in Aberdeen
[8] Net emissions are still being calculated.

Soil health is a primary concern for agriculture on the prairie. Frick et al recently published findings from a simulation constructed to estimate organic carbon change in agricultural soils of the Canadian Prairies that found that all provinces are sequestering SOC (soil organic carbon), but not at equal rates[9]. The most promising areas for soil carbon sequestration (SCS) are in the Black soil zone, which includes 40% of total cultivated area. In general, fine textured, level, lacustrine parent material soil landscapes had the lowest SOC loss rate in the fallow system, and the highest SOC gain rates in continuously cropped systems: the opposite was true for soil landscapes with medium textures, steeper slopes, hummocky surface forms, and glacial till parent material.

Up until now, the common approach to studying CO_2 emissions has been to collect data and develop a model. Soil scientist Dan Pennock suggests that there is little need to repeat field studies because the soil survey is complete and a broad brush is not so necessary anymore. He indicates a need to apply the models and improve them for various landscapes, particularly non-level landscapes. In fact, carbon emission mitigation is near the point of implementation.

While Alberta is gaining 2.5 Tg yr. (-1), Saskatchewan (which has the most cultivated area) has the lowest rate of SOC gain because it has the highest area of summerfallow. Frick et al suggest that a shift of 10% of the cultivated area within each soil zone to a system incorporating increased crop frequency, the prairies could gain SOC approximately 1.9 Tg yr. (-1) faster than with 1996 land-use, for a total SOC sequestration rate of 7.7 Tg yr. (-1).

Dan Pennock has been involved in GHG research for the past ten years. He indicates that one area still somewhat neglected is NO_2, which provides an excellent opportunity for emission reduction through limiting fertiliser use. This would reduce costs and emissions simultaneously.

Louise Nelson, a soil microbiologist with the University of Saskatchewan, is optimistic that fertiliser reduction can be enabled using genetically modified organisms (GMOs). Despite the trepidation Europe has shown towards importing GMOs, the possibilities for nutritional enhancement and reduced costs (herbicide and fertiliser) are too great to reject the area. The European market is relatively small, and the importance of the Pacific Rim continues to grow for North America. China is heavily involved in GMO research and receptive to GMO crops.

3.3 Nitrous Oxide

A number of agricultural activities add nitrogen to soils, thereby increasing the amount of nitrogen available for nitrification and denitrification, and ultimately the amount of N_2O emitted. N_2O emissions can be divided into two broad types:

Direct additions refer to the application of synthetic and organic fertilisers, application of sewage sludge, application of animal wastes, production of nitrogen-fixing crops, application of crop residues, and cultivation of histosols, and through direct deposition of animal wastes on pastures, range, and paddocks by grazing animals.

Some of the nitrogen that is applied to agricultural fields is transported off site by volatilisation and subsequent redeposition, or leaching and runoff. The nitrogen that is

[9] A. Frick, D. Pennock, K. Elliott, and D. Anderson. *Simulation Modelling to Estimate Organic Carbon Change in Agricultural Soils of the Canadian Prairies.* Saskatchewan Centre for Soil Research Publication No. M144. Saskatoon, March 2000: p ii-v.

transported from the agricultural field will provide additional (indirect) nitrogen for subsequent denitrification reactions that will produce N_2O.

4 Greenhouse Gas Sinks

The Subsidiary Body for Scientific and Technological Advice (SBSTA) convened in June 2000 and did not issue any decisions regarding agricultural soil sequestration. The negotiations will continue in November. However, good practice guidelines were issued, which clarified livestock population characterisation, and calculating emissions for livestock, manure management, and soils. The activity coefficients provided favour cattle and buffalo grazing on large areas compared to those confined to a stall, for example. Therefore, stakeholders that want to improve Canada's emissions calculations could encourage cattle producers to keep their herds on pasture.

There are aspects of zero till management practices that are still poorly understood. Darwin Anderson, a soil scientist with the University of Saskatchewan, suggests that while the carbon sequestration potential for zero till is significant, it is susceptible because the carbon is stored near the top of the soil. He suggests research into sequestering carbon deeper into soil, for example to develop plants that move the carbon deeper, while thriving on the clay part of the soil. Some assumptions have to be set aside to attempt this kind of research, since moving carbon deeper will involve tilling to move it lower. Anderson also suggests research into the denitrification potential of zero tillage, and to incorporate full cycle carbon accounting into studies.
In the past the emphasis has been on tillage and management with carbon. A more interesting and fruitful approach may be to re-establish grasslands. Projects have been undertaken where comparisons of organic matter were made between those under cover for the past ten years against those that have been farmed conventionally.

Producers are increasingly incorporating the zero till method. It is more management intensive, but requires less machinery (although an investment in new machinery does still have to occur). Zero-till also brings more reliance on fertiliser, which is a major source of nitrogen, and herbicide (not a GHG). Most importantly, zero-till methods can contribute significantly to soil carbon sequestration.[10] Britain is aiding zero-till projects in Costa Rica as a joint implementation project. Canada could investigate similar international projects. The Century model predicts that agricultural soil will be a net sink by 2010. The Sinks Table has shown concern that a soil carbon verification method would have to be developed in order to quantify any gains made.

These methods, when properly adopted improve the resources that producers rely on. Equally, mitigating methane and nitrous oxide emissions through decreased fertiliser and fuel use should significantly reduce input costs, but have more important implications for reduced pollution. Cost internalisation requires combining potential environmental and economic conditions to conclude a net loss or gain.

[10] No-till is imperfect in other ways. For wetland habitats, it becomes a mixed bag. While the improved soil prevents problems associated with erosion, stubble can become a trap for wildlife that nest in it.

5 Canada's National Process for the Study of Climate Change

Federal, provincial and territorial ministers of energy and the environment met in early 1998 and approved a process that would form the basis for Canada's national implementation strategy to address climate change. The focal point of the national effort is the Climate Change Secretariat, sponsored by the federal government.

The National Climate Change Secretariat manages and supports the national engagement process and the development of the national implementation strategy. It is responsible for consolidating and integrating the work from the Issue Tables and other processes. It operates as a virtual office with federal and provincial staff operating from their existing offices[11]. A National Air Issues steering committee and National Air Issues Co-ordinating Committee on Climate Change (naicc-cc) provide advice and overall direction for the management of the national process.

Expert committees of limited size, called Issue Tables/Working Groups have become the main method of soliciting external input. Issue Tables/Groups examine the impacts, costs and benefits of implementing the Kyoto Protocol and analyse the various options to allow Canadians to reduce GHG emissions and meet the climate change challenge.

Soil carbon sequestration is widely researched, difficult to document, prone to variables and not recognised yet as a sink by the SBSTA. Despite all this, it holds enormous potential both as a carbon sink, and as an incentive to improve soil quality. It also could become a value-added product if marketed as quantifiable emission credit. The official action plan of Canada includes SCS as an aspect of sustainable agriculture. A related global warming issue is the role of CO2 emissions and the availability of agriculture to act as carbon sink. For agriculture, a significant aspect of carbon accumulation in soil is the relationship between healthy soil and productivity. Soil as a sink for carbon to reduce the potential accumulation of CO2 in the atmosphere would be a secondary opportunity, but the two issues are inseparable. Louise Nelson emphasises that SCS is not a long-term solution. She advocates a whole-system approach that improves fertiliser efficiency, perennial crops on wasteland, and efforts to support fast-growing forestry. Use of plants as a source of plastics could also be encouraged. Phytoremediation also influences the carbon flow.

5.1 National and Provincial Studies

Policymakers can encourage energy efficiency and other climate-friendly trends in both the supply and consumption of energy. Efficiency can be improved in large part by providing an economic and regulatory framework for consumers and investors that promotes cost-effective actions, the best current and future technologies, and "no regrets" solutions that make economic and environmental sense *irrespective of climate change.*

[11] Summary of key players

Taxes, regulatory standards, tradable emissions permits, information programs, voluntary programs, and the phase-out of counterproductive subsidies can all play a role. While the government of Canada has made several changes to its tax laws that support climate change, renewable energy and energy conservation efforts, none of the alterations are targeted at producers interested in adopting management methods reducing emissions. For example, the 1996 federal Budget improved access to financing for renewable energy and energy efficiency by expanding the eligibility for flow-through shares to include pre-production costs pertaining to eligible investments in the renewable energy industry. Companies undertaking energy efficiency and renewable energy investments can claim the accelerated tax write-offs association with these investments against income from all sources. Pre-production costs would be 100% deductible and now could be renounced to shareholders under a flow-through share agreement.

The Saskatchewan government's stated priority is to support economic growth and security, and there are numerous opportunities to combine this goal with emission reduction. The connection between emission reduction, best management practices, and cost reduction has already been discovered. In the recent budget address, Finance Minister Eric Cline noted that research developing pulse crops, organic farming and livestock processing is "bolstering growth and opportunity in agriculture and agrivalue".

Many projects currently being conducted in Saskatchewan have relevance to climate change, though not all of them are classified as such.

Soil conservation projects have the objective of adjusting agricultural practices to reduce the loss and enhance the productivity of valuable topsoil. As a result, these projects may increase the uptake or reduce the production of GHGs namely CH4, N20 and photochemically important compounds such as CO and Nox's. In many cases, soil conservation projects incorporate the use of specific vegetation species to stabilize soils, increase nitrogen fixation and improve soil fertility.

Robert St. Pierre heads the Native Fruit Development Program, which receives its core funding from ADF. It is fundamentally concerned with promoting diversification and woody perennials, both of which are recommendations for ameliorating climate change. Because the fruit bushes are perennials, there are good carbon fixers, but the question remains how much CO_2 are they capable of sequestering. However, the potential for adding value to shelterbelts is excellent, and possibilities for including fruit as a rotation exist. There is some evidence fruit could approximate the return on crops in certain areas. Encouraging fruit production could also help humidify areas by affecting rainfall and winds.

Soil enhancement projects have the specific objective of expanding specific vegetation species within the farming system to stabilize it, boost productivity and/or provide wood raw material or opportunities to expand the income base. This should also increase the store of carbon (and nitrogen) within the system.

Livestock production projects have the primary objective of either improving the productivity or increasing the production of the livestock sub-sector. The results of a livestock project can either increase or decrease the net GHG emission, primarily methane, depending on the objective of the project. If the objective of the project is to increase the productivity of the livestock sub-sector, the result may be a net decrease in GHG emissions.

However, if the project simply increases the production of livestock, the result may be an increase in GHG emissions.

6 Climate Change and Adaptation Research

Adaptation as stated in the National Action program on Climate Change- 1995 "...adaptation refers to... sustainable adjustments to future changes in the global climate, such as... increases in the frequency and magnitude of hazardous weather... Adaptation actions may be expected to provide net economic benefits in the short term, in addition to reducing vulnerability to climate change in the longer term". In fact, much of the ability to respond is derived by shorter tem actions that may be due to policy changes related to economics, land, water, or biological resources. The choice becomes whether to encourage production systems that increase trash cover and reduce erosion or favour production methods that will increase the risk of erosion.

In terms of adaptation, Anderson suggests that agronomic research using future scenarios would be valuable, especially when considering the future of Saskatchewan's boreal forest and the possibility of agriculture moving north. Forestry may literally "go up in smoke", and the area could prove useful for agriculture, even though it is likely to be acidic.

While the merits of emission reduction (mitigation) are considerable and worth implementing in any scenario, mitigation is only one aspect of climate change as it relates to human society.

Research on GHG emissions has been undertaken on the Prairies for many years although the larger impetus took place after the Kyoto meeting of December 1997. The technologies that show some verifiable low-cost reduction in GHG emissions involved carbon sinks that are currently not part of the Kyoto Protocol.

Saskatchewan farmers are familiar with the unpredictable nature of weather and climate, and it is unrealistic to assume that reducing anthropogenic emissions will halt climate change in its tracks. For the most part, human settlements will have to adapt to an increasingly dynamic climate. The best protection in this case is information, and a holistic understanding of the ecosystems that we depend on. This is particularly true for the agriculture industry, which is more vulnerable than most to the vagaries of the weather. Therefore, climate change research is not necessarily focused on Kyoto requirements or anthropogenic greenhouse gas emission. The research encompasses all aspects of the issue with the view that whether Kyoto is ratified or not, human societies will have to address climate change.

6.1 Adaptation, Agriculture and Water Resources

G.M. Luciuk and E.G. O'Brien recently released a paper for the Prairie Farm Rehabilitation Administration that suggested climate change concerns are likely going to be overshadowed by shorter term impacts on markets and prices related to global markets, government fiscal capacity and in some cases, environmental conventions. They recommended that

considering the context, in which agricultural research is being conducted, the focus of climate change research and analysis should be on adaptation and promotion of medium term flexibility/sustainability of the agriculture sector as opposed to macro-impact assessment and loner term macro solutions. Some long-term study needs were suggested including the cyclical nature of climate variability and water supply, impacts of increasing aridity on expansion of salinized lands and the relationship of carbon sequestration to questions of agriculture and water management.

6.1.1 Sustainable Agriculture

In both theory and practice, the principle of sustainable agriculture is affected by climate change. Sustainable agriculture is flexible and reactive. It is not a specific farming practice—in fact, sustainable approaches bust be tailored to every individual landscape. For example, organic farming methods may improve certain farms, but actually contribute to soil degradation in other areas.

Sustainable agriculture is more a philosophy or destination motivated by a balance of social considerations, environmental and economic concerns. If successfully applied to climate change, it would enhance the quality of life for farmers and society, providing an equitable return to producers while at the same time satisfying consumer needs for food and fibre[12].

> Charles Maule is an environmental engineer who recognises the connection between climate change and soil hydrology—determining whether enough water is available for dryland crops and maintaining soil quality without water pollution. This involves measuring snowmelt, and runoff, and a complete understanding of dryland hydrology. Concerns with tillage practices and black fallow are involved, along with depth of seeding and increased pesticide use. Maule suggests that in the event of global warming and an increase in the length of growing season, wetland preservation may figure prominently in a sustainable agriculture. He also cautions that global warming may induce a positive feedback, where emissions increase with the temperature.

Researchers and scientists are reaching a consensus on the correlation between conventional agriculture and erosion, contamination, pollution, farm foreclosures, and dying rural communities[13]. The Saskatchewan government is committed in principle to promotion of sustainable practices, and many projects funded under this aim also contribute directly to climate change abatement. ADF has awarded extensive resources to develop soil management practices that improve organic matter and reduce salinity. Soil and water conservation is a high priority for the ADF because the success of the agricultural industry depends on quality resources.

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[12] Patricia Fornesse, unpublished paper

[13] Kowalski, Joanne, 1993. Sustainable Agriculture: Definition, Debate and the Implications for Extension." Unpublished manuscript.

SECTION II

RECOMMENDATIONS

7 Recommendations

Recommendations have been subdivided into 3 sections:

- Core Recommendations
- General Recommendation
- Recommendations from Scientists

7.1 Core Recommendations

The following "core" recommendations are drawn from information gathered for the report and consultations with experts at the University of Saskatchewan. They can be carried out through conventional research studies or the funding of students thesis, help in acquiring sophisticated equipment or through some other "strategic" program.

Internationally, reduced/zero tillage and summerfallow elimination are the practices that most countries agree can sequester carbon, and if sinks are included in the protocol, those activities will probably be among the first accepted. Manure management and the improvement of animal feed are also to be considered critical.

Verifiable GHG coefficients for methane, carbon dioxide and nitrous oxide emissions are still required and since Saskatchewan has the bulk of the zero till and summerfallow acreage, much of the work should be done in Saskatchewan.

Recommendation 1.

Crop Production Practices and Soil Management Technology.

Support research on soil-conserving crop production practices and zero tillage/elimination of summerfallow soil management projects that sequester carbon. Support the further study of projects that have good carbon sinks potential, such as agroforestry and reduced CO_2 emissions such as renewable fuels.

Recommendation 2.

Feeding, Grazing and Manure Management Systems

There exists a significant need to improve manure storage and handling systems. Hence, the encouragement of the development of short-term and long-term systems that reduce methane emissions from cattle and hogs should be supported.

These projects should include the study of advanced feeds and the enhanced management of manure in storage and field applications.

Recommendation 3.

Public Outreach

Initiate a public outreach program on climate change concerns and opportunities for producers.

While there is an Issue Table devoted to Public Outreach, its funding through the Climate Change Action Fund is specifically targeted at non-governmental organizations and providing climate change information through schools. To date, there has been no public awareness program aimed at producers.

Recommendation 4

Whole Systems

An excellent opportunity exists to include an approach in climate change research that considers efficient land management and use, animal and manure management, carbon sequestration and reduced GHG emissions as "whole systems". Support research that examines climate change as a "full cycle" issue rather than discrete, single or specific-objective research.

Overall, climate change research also requires initiatives that are sustainable in the long run. Every issue, whether it is an agronomic, animal management, health, water supply/quality issue etc. must have a long-term sustainable management perspective.

7.2 General Recommendations

1. Support studies that examine the various carbon credit systems that are potentially viable in Saskatchewan;
2. Support research and development of organic crops in appropriate areas which may feature a higher profit margin than conventional crops and often less emissions;
3. Support research that will increase the efficient use of farm machinery and reduce the use of non-renewable fuels;

4. Support projects that sequester carbon, including those related to permanent land cover, shelterbelts, agroforestry and fruit cultivation. These projects will often make conversion of marginal lands more economically attractive for producers;
5. Support initiatives that make pastured cows economically feasible. Cows on pasture release less methane;
6. Support research on:

- Reduced and more efficient fertilizer use;
- Improved plant varieties that require less nitrogen;
- Improved management practice where fertilizer is applied only where necessary;
- Improved soil that reduces the possibility of leaching.

7. Encourage joint studies that measure both carbon and nitrogen;
8. Encourage wetland and slough retention - their loss could aggravate a drought situation;
9. Continue to, or increase support for diversification initiatives that feature low environmental impact. The more diverse a landscape is, the better equipped the area is to withstand environmental stress - for example, natural fruit expansion activities;
10. Support research into animals that are adaptable to the environment and that make use of native grasses efficiently - such as bison production;
11. Consider research on water facilities which may become stressed under drier conditions;
12. Support research of drought-hardy crops;
13. Support research that anticipates and alleviates manure problems related to intensive livestock operations;
14. Support studies into the ethanol industry and other alternative fuels;
15. Support research into the use of anaerobic sequencing batch reactor (ASBR) systems, biodigesters or other technology in recycling methane and producing electricity from manure;
16. Support research into transportation issues. Consider encouraging more producers to take on a domestic orientation—if the product is consumed within the region, carbon emissions related to transport can be reduced;
17. Support work that provides for the "full circle accounting" of carbon sequestration that incorporates studies of, for example, the effects of carbon-nitrogen ratio[14].
18. Support work that will provide better accounting of "baseline" GHG numbers[15].

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[14] By sequestering carbon in the soil, a certain amount of nitrogen is also sequestered. This fact should be taken into account when accounting for carbon sequestration. This nitrogen could be "locked up" for quite a while.

[15] Baseline = the conventional practice. May be amended by including early action.

7.3 Recommendation from Researchers

1. We will have a major problem in maintaining the quantity of our water supply. The water supply on which Western Canada is dependent - that is the glacier fed stream on the Eastern facing glaciers in the Rockies - are degrading and degrading at an increased rate because of increased temperature. If these supplies come to the point where they can't maintain the water supplies we currently have, we can visualize a situation where Saskatchewan and Manitoba will be in a precarious position because Alberta gets a first crack at the water. If it comes down to a struggle, Alberta will win out. The water needs in Alberta - especially their southern irrigation region - is tremendous. We could easily face a situation of minimum water flows under the Prairie Provinces Water Board Agreement if that agreement was not honoured by Alberta and there is a legal school of thought that there may be ways of violating it.

From the point of intensifying our research - not only from an engineering, agriculture, social science and health sciences - the whole scheme of disciplines will have to be involved in finding ways in which we can reduce our dependence on our supplies of water by:

1. Reducing our dependences on water by instituting minimum water usage situations;
2. Developing plants that don't need as much water as they do now;
3. We need to look at conserving what we have - use less water, use water more efficiently, consider re-use - all of these things are integrated aspects that need more research.

We need to understand where we are going in the next 30 or 40 years in terms of water supply, given the climate change scenarios that are forecast. Before ADF embarks on funding, it should set up a committee of water users to provide advise - very much like they do in the irrigation area - on what we should do and where we should go with our water.

2. Much of the current N_2O research is done on small plots on a very level landscape and on very good soil. What we feel we need to be doing is getting a handle on better provincial and Western Canadian estimates. Basing N_2O emissions on a few little plots is not going to be enough - so it needs to be scaled to bigger plots and rolling topography that is more typical of the landscape and on different soil zones. There is a lot of work on the validation of carbon model locally - using models and getting all the background data to calibrate the model with local data. We need to get more and better data so that we can estimate N_2O fluxes better.

3. One of the problems in the approach that researchers are taking is that they are looking at carbon and nitrogen separately from one another. Biological cycles are very closely related to each other. Much focus has been into carbon sequestration and not taking into account what sequestering carbon is doing to the nitrogen cycle.

What if things farmers are doing - minimum till and low till that are supposed to be sequestering carbon - theoretically increase N_2O emissions because they harbour a lot

more moisture in the landscape[16]? This is an area that needs to be looked at - the link between carbon cycling and nitrogen cycling.

4. The idea of using zero tillage to sequester more carbon needs to be researched carefully. Under the right set of circumstances there may be more denitrification with a large amount of soluble carbon in the soil through increased fertility levels. Coupled with cool, wet conditions, denitrification and nitrous oxide evolution from the soil results. If the farmer uses fertilizers, chances are that there may be more nitrogen going back into the atmosphere than models may predict.

5. Scientists look at terrestrial systems, so that when they are in fields they avoid sloughs because it is not really agriculture. On the other hand, the "aquatic" scientists look at aquatic systems in sloughs - they don't look into the surrounding land - the catchment area - and so there is no real link between the two. We have emissions from agricultural land - they have emissions from wetland areas - but there is nothing on how the two are linked together. This is one thing that needs to be looked at - how these whole areas are integrated.

6. Within Saskatchewan there are 8 Ecoregions - determined by the vegetation and by primarily water and organic matter[17]. Carbon models are being calibrated with local data - we need to do the same thing for nitrous oxide. Improved data is needed to calibrate the N_2O emissions models to Prairie conditions and so we will be able to see how good the models are.

7. There has to be a better way to move from small plot measurement to landscape scale area - for example by using portable laser scale instruments. ADF needs to look at funding infrastructure to support better equipment for "climate change" type of work.

8. Support the study of the biological treatment of manure. As the province attempts to diversify the economy, the runoff from animal manure will be a big problem in Saskatchewan. The province has always relied on "diluting the pollution" instead of properly treating it and in some respect, land application is not a proper treatment. Once ground water is contaminated, it is contaminated for a long time. In terms of climate change issues, this is a very important one.

9. ADF should provide strategic funding for students' research in climate change as long as it is well managed. ADF should set up the infrastructure to do this type of research.

10. Support the study of the reestablishment of grassland areas on Prairie soils - especially on some of the lower quality, highly eroded, degraded soils that may have a high carbon sequestration potential. There is not much organic (carbon) matter in these soils now, so the potential for large carbon sequestration in the future is high.

11. Research that would be very practical is to reexamine the permanent cover sites that have been going for about 10 years to see what kind of organic matter levels have developed in those soils. There may be a problem with this in that we don't know

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[16] Which is one of the major triggers for N_2O emissions.

[17] Those are the same driving forces for N_2O and CO_2 emissions.

what the levels were 10 years ago but scientists can select proxy fields - nearby fields - that has similar soils and similar looking fields.

12. One area that may be important is to take a more careful look at what is really in the soil in terms of organic matter[18]. We have always looked at organic matter as being the product of biochemical and microbiological processes in the soil. But we are starting to question how much of the "black stuff" in the soil is basically charcoal (the residue of prairie fires that may have happened many years ago). From a biological point of view, charcoal is not something that microorganism would use as a nutrient sources.

If we want to improve on our models - the CENTURY model for example - and come up with a better way of understanding to processes that go on in the soil, we should know more about the actual material that is in our soil.

In the very black soil, perhaps a half of the organic matter may well be charcoal[19]. This would behave quite differently when trying to calibrate a model as most models are based on microbial processes.

13. There is a potential for carbon sequestration in zero tillage but it is a limited potential in terms of the amount per acre. There are a huge number of acres - which is the attraction - but the amount per acre is (significant) but not large. The amount that is sequestered tends to be near the surface of the soil. It is therefore quite susceptible to decomposing and going back into the atmosphere.

There should be long-term research into ways of moving the carbon deeper into the soil. We need to look at sequestering carbon further down and in complex with the clay mineral soil. One way would be to develop plants that put more of the carbon they take out of the atmosphere deeper into the soil.

This has never been the objective of plant breeders. Varieties are always chosen for grain yield and the material below ground has always been considered lost energy because farmers receive nothing for it. Varieties could be designed with deep roots to meet this criterion.

14. Agronomic methods could be developed that might periodically invert the soil so as to try to move the carbon deeper into the soil. This would involve tilling the soil so there might be a short-term loss of carbon - whenever the soil is tilled there is a loss - but in the long term there would be a layer on the surface that is low in organic matter but that would be gradually built up over time[20].

The goal of this work would be to build a soil that would have an organic matter rich layer of topsoil that might be 20 cm thick rather than 10 cm thick[21]. Instead of having the potential of storing 5 or 10 tonnes of carbon per hectare in the soil, it could be 30 or 40 tonnes per hectare.

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[18] Although not entirely related to climate change.

[19] Charcoal is quite inactive biologically but quite reactive in terms of processes like absorption. If it is in the soil it may be related to the degree of tie up of soil-applied herbicide. A lot more herbicide needs to be applied to a black soil with a lot of organic matter than a brown soil with a low organic matter. It is possible that charcoal is important in that area as well.

[20] This research would run over 10 - 20 years or more.

[21] This research would need to be done carefully because of the problems associated with soil erosion etc.

This type of long-term research really needs to be funded right now.

15. Any kind of modelling exercise intended to estimate the carbon sequestered in the soil really requires a link back to the actual kinds of soil. Continuing an effort to develop the good soils maps that are required to make that link is very important in the long term. We have in Saskatchewan some of the best soils maps developed with generous funding from ADF and others. A modest investment in maintaining that database - keeping it up to date with all the new advances in GIS - looking at ways of scaling up and down or taking semi detailed maps and, through image analysis, making a more detailed map that can be used in farmers fields will lead to better ideas for local to regional carbon sequestration potential.

16. There is a need for agronomic research of ways of putting different kind of crops on different kinds of soils in different climatic areas. We need to match different climate scenarios with the available soil resource to get an idea of the cropping patterns of the future. We need a better idea of what lies ahead. Certain crops will move from the dryer, warmer parts into the boreal areas and the black and gray zones. If there is a substantial warming of the climate, probably a whole suite of crops will be moving. Agronomic research will be needed to ascertain the best management practice for that particular combination.

With the change in climate, the boreal forest may disappear (through forest fires, for example) so that the boreal forest will no longer be productive forestry but it could become an agricultural region. The soil resource in that area is pretty limited. If agriculture was to move up there, there would need to be a lot of research into acidic soil and soils that may be deficient in nutrients (nitrogen, sulphur, etc.).

17. Mitigation of GHG revolves primarily around using microorganism and whether they can be used more effectively to reduce GHG emissions. There is a need for better measurements of what is actually happening. Many of the microorganisms are involved in producing carbon dioxide, methane and nitrous oxide and it takes a "whole systems" approach to look at that so there is a need for soil scientists and atmospheric scientists to work together to measure these systems.

Can we use soil microorganism better to reduce GHG's - for example to improve the efficiency of fertilizer (organic, applied as manure, or chemical) utilization? Microorganism show enhanced activity near the root region - plants produce carbon substrates that provide nutrients for organism. There may be ways of looking at the root region to alter oxidation by the plants to enhance the activity of beneficial organism so that more nutrients is taken up by the plant rather than recycled.

18. Research the use of perennial crops that produce high root mass - in particular the use of perennial legumes that fix their own source of nitrogen and so decreasing the need for nitrogen fertilization. Increasing the use of legumes in rotation decreases the need for nitrogen fertilizer. As part of this, you need the appropriate bacteria that can form the association with the legume root. This research is becoming very important with pulse crops.

19. Research what is the best way to partially degrade the manure produced from increasing animal production on the Prairies before putting it on fields as fertilizer? What is the best way of applying it on fields so that it is not converted into nitrous oxide?

20. There is a role for biotechnology - for example modifying plants to grow quickly and thus capturing the CO_2 through photosynthesis and then being recycled for use. There is a need for research into the use of microorganism as a source of, for example, plastics that would normally be made from hydrocarbons.

Microorganisms naturally produce some polycarbohydrate-type materials that have the same properties as plastics so that we could move from a hydrocarbon-based economy and move to a more natural plant-fibre based or microbial-based production of compounds. We should also be looking at moving some of the enzymes from the microorganism into plants so as to produce plastics and other consumable goods directly from plants.

21. If we are moving to warmer and dryer climate, there is a need to develop crops that are resistant to temperature and drought stress. There will be a need to study the associated microorganism - for example, there may be changes in terms of pests or fungi etc[22]. Looking at legume crops, it might be possible to grow soybeans and other crops in Saskatchewan (such as one sees in the US mid West) by developing microbial systems that can fix nitrogen and that can deal with the stress of temperature and drought. There may be opportunities to adapt soil microbial populations to function more efficiently under changed climatic conditions.

[22] There are approaches using biotechnology that can deal with these.

SECTION III

KEY PLAYERS INVOLVED IN CANADIAN CLIMATE CHANGE POLICY AND RESEARCH

8 Key Players

8.1 Inventory of Canadian Agri-Food Research (ICAR)

ICAR is a comprehensive and up-to-date database for agriculture and food research in Canada and is a product of the Canadian Agri-Food Research Council (CARC). ICAR contains detailed information on current research projects in agriculture, food, human nutrition, aquaculture and related areas of biotechnology. Currently, ICAR describes over 2,400 projects from industry, universities, and provincial and federal establishments. ICAR can provide useful and timely information to research managers, research planning and co-ordinating committees, industry associations, funding agencies, researchers and all others concerned with research and development and technology transfer in agriculture, food and related areas in Canada. For each project, ICAR provides its title, objectives, and known and anticipated impact of the research, a status report and the names of the researchers and the research establishment. It indicates the research effort in terms of person-years and the focus of the research in terms of commodities or resources and in terms of functions and disciplines. Descriptive keywords and the names and addresses of funding sources and organisations are also included.

ICAR is very flexible and provides a wide variety of reports and report formats such as:

- compilations of research projects on a specified commodity and/or discipline;
- lists of researchers and their projects in specific disciplines;
- lists of all research projects in a region, province, establishment or sector.

8.2 Canadian Agri-Food Research Council

The Canadian Agri-Food Research Council (CARC) is a national co-ordinating system for agri-food research and technology transfer in Canada and is a catalyst for building consensus on related priorities. The CARC committee system consists of participants from all sectors (industry, university and government) who identify issues and opportunities to be addressed through research. CARC provides leadership in co-ordination and networking of research and technology transfer and is a catalyst for building consensus on research prioritisation in Canada. In this regard, research and technology transfer is directed to assist

the agriculture and food industry to be globally competitive, environmentally sustainable and socially responsible. The objectives of the organisation are to:

- Identify emerging research and related educational issues and develop recommendations to address them;
- Co-ordinate and act as a catalyst for research prioritisation in Canada;
- Be a catalyst for commodity, product and issue specific strategic planning;
- Foster the building of partnerships and networks among industry, governments and universities to address issues of mutual concern and develops collective solutions;
- Communicate the networking and co-ordination of CARC's activities in the area of research and technology transfer;
- Review and renew the National Strategy for Agri-Food Research and Technology Transfer on an on-going basis.

8.2.1 CARC Priorities

- environmentally sustainable continuing decline in support for soil survey and related interpretative and land evaluation work in particular maintenance of soil survey databases impact of modern technologies such as zero tillage and precision agriculture on soil and environmental quality, and therefore sustainability
- manure management particularly with reference to large, intensive livestock operations such as swine barns, cattle feedlots, poultry and dairy industries (e.g. reduce odour, optimal timing and amount of manure applications, alternative storage methods, alternate uses, noise and dust); managing manure remains a significant deterrent to the expansion of the livestock industry
- research into maintaining or further improving water quality and use efficiency used for agricultural production or human consumption
- soil testing methodologies; carbon sequestration in agricultural lands; greenhouse emissions and their measurement and; greenhouse gases control.

8.3 Canadian Adaptation and Rural Development (CARD)

The 1995 Federal Budget established the Canadian Adaptation and Rural Development (CARD) Fund allocating $60 million annually for regional and national initiatives. It was put in place to help the agriculture and agri-food sector and their rural communities to adapt to major government agriculture policy changes involving the reduction in safety nets, removal of transportation subsidies, and more open global competition.

The CARD has acted as a catalyst to facilitate change in strategic areas, complementing existing AAFC and other federal programming. One of the focus areas for the CARD funding has been to support the enhancement of environmental sustainability of the agriculture and agri-food sector. Consideration of and support for environmental sustainability objectives has been integrated into the spectrum of CARD initiatives. Three CARD funded programs that have a specific environmental sustainability focus include:

- the National Soil and Water Conservation Program (NSWCP) which was initiated to complement AAFC's Sustainable Development Strategy (Agriculture in Harmony with Nature - Strategy for Environmentally Sustainable Agriculture and Agri-food Development in Canada) and to help the agriculture and agri-food sector address its priority environmental sustainability issues.
- the Hog Environmental Management Strategy (HEMS) which is helping hog industry stakeholders address major environmental issues that are limiting the expansion of the hog industry in Canada.
- funding for the National Agriculture Environment Committee (NAEC) which is a farm forum with industry representation from all the provinces. The NAEC discusses, studies, and develops proactive strategies, solutions and projects on key environmental issues facing the agriculture and agri-food sector.

To enhance environmental sustainability CARD funded projects normally involve one or more of the following: human resources development; research and development; infrastructure support / environmental stewardship; and improved market information /utilisation. These activity areas are consistent with the four strategic directions of AAFC's Sustainable Development Strategy.

Progress reports completed for the 1997- 1998 fiscal year provide an indication of the nature of activities that are being supported by CARD funded initiatives. In 1997-98, some $4 million of federal CARD funds supported environmental sustainability initiatives costing around $14.6 million. Industry direct and in-kind funding contributed 70% towards the cost of environmental initiatives carried out.

8.4 Climate Change Fund for Research in Agriculture

The CARD Climate Change Funding Initiative in Agriculture (CCFIA) is a $4 million over 4 years (1999-2003) program on addressing current knowledge gaps into the impacts of agriculture practices on greenhouse gas (GHG) emissions and on the development of new technologies which reduce those emissions and increase carbon sequestration[23].

The Climate Change Funding Initiative in Agriculture's goal is to address the areas of greatest research needs and early actions, to help the agriculture sector in meeting Canada's Kyoto commitment in greenhouse gases. These areas of needs have been outlined in the Agriculture and Agri-Food Climate Change Table Options Report. Applicants for any of the funds will have to address issues related to identified research needs in key areas of early mitigation such as: crop nutrient management, livestock nutrient management, manure management, carbon sequestration and bio-fuels. In establishing these funds it has been recognised that expertise in areas identified may initially not be available in Canada. A key objective is to facilitate the development of the expertise in Canada and in the process address Canada's priorities in meeting greenhouse gas reductions. The approach will have four key components:

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[23] http://www.carc-crac.ca/english/climatechng/pur-proc-e.htm

- Developing Canadian Human Resources;
- Science Networks for Climate Change in Agriculture;
- Industry Matching for Climate Change in Agriculture;
- Workshop on Climate Change and Communication.

Applications will be received from three groups: agriculture universities; consortia from universities, federal or provincial experts; and industry. The selection committee will balance the awarding of contracts so that all areas of needs as identified by the Climate Change Table will be covered.

8.5 Climate Research Network

The Climate Research Network was established in 1993 by the Meteorological Service of Canada (MSC) of Environment Canada as part of the Federal Government's Green Plan. Its activities are included as one of Canada's scientific commitments in the National Action Program on Climate Change tabled with the Conference of the Parties to the Framework Convention on Climate Change. Within these commitments, Canada contributes research to the World Climate Research Programme to provide more complete answers to a number of key policy questions.

The National Climate Change Secretariat manages and supports the national engagement process and the development of the national implementation strategy. It is responsible for consolidating and integrating the work from the Issue Tables and other processes. It operates as a virtual office with federal and provincial staff operating from their existing offices

8.6 Department of Foreign Affairs and International Trade

The Department of Foreign Affairs and International Trade is heavily involved with negotiations related to the Kyoto Protocol. The Action Plan developed by the Department includes several goals related to the negotiations and to the climate change issue:

- Engage in further negotiations on climate change issues under the Kyoto Protocol, with the aim of concluding a legal instrument on commitments for the post-2000 period.

- Identify those mechanisms established under the Kyoto Protocol that will be further developed.

- Study all taxes, grants and subsidies to:

    - identify and eliminate barriers or disincentives to sound environmental practices
    - support and contribute to The Intergovernmental Panel on Climate Change

8.7 Agriculture and Agri-Food Canada

The Policy Branch of Agriculture and Agri-Food Canada has a mandate to provide the Government of Canada with timely information on the impacts that proposed new policies could have on the agricultural sector, or what the possible outcome would be if existing policies and programs are altered. Increasing emphasis is being placed on the interrelationships between environmental stability and the farm management practices promoted by agricultural policies. However, to date there has been a lack of quantitative tools that could be used to address this issue.

A series of Technical Reports which document an integrated agri-ecological economic modelling system that can be used to simultaneously assess the economic and the greenhouse gas emission impacts of agricultural policies at regional and national levels. The model provides a quantitative tool that can contribute to policy analysis related to Canada's Kyoto commitment to reduce greenhouse gas emissions.

8.7.1 Policy Analysis Division

The Policy Analysis Division carries out economic analysis in support of the Branch's mandate of policy monitoring and development. Large-scale computer models are maintained and utilised to provide quantitative assessments of how changes in market conditions and/or policies could affect the well being of the agricultural sector. Primary level models and cost of production data are maintained to analyse policies and programs and demonstrate primary sector impacts. International and domestic conditions are monitored and assessed on an on-going basis.

8.7.2 Structural and Environmental Analysis Unit

The Structural and Environmental Analysis Unit focuses analysis on resource utilisation and regional/sector impacts. It integrates economic information with environmental analysis to facilitate policy formation for sustainable development. A set of farm-level models, by farm type and size, are maintained to provide an understanding of the implications of policy change for individual producers in relation to other factors that affect their production and investment decisions. Input, output and productivity trends measure competitiveness and track policy impact.

8.7.3 The Saskatoon Research Centre

The Saskatoon Research Centre and its research farms bring a long-term commitment in crop research to the agri-food industry in western Canada. The centre delivers improved germplasm of oilseed and forage crops crop-production and pest-control practices for the Parkland region research to expand the utilisation of prairie crops conservation, documentation, and distribution of diverse germplasm by Plant Gene Resources of Canada. Biotechnology and chemistry strongly support each program.

Construction of the south wing of the Saskatoon Research Centre, which includes the greenhouse-headerhouse complex, several laboratories, and Plant Gene Resources of Canada, is now complete. Plant Gene Resources of Canada transferred seed from Ottawa to its new facilities in April of 1998. A new field services building nears completion at the

Saskatoon farm site. The facilities will house laboratories for seeding preparation, data processing, and oilseed analysis. It will facilitate efficient post-harvest processing of field samples.

8.8 The Semiarid Prairie Agricultural Research Centre

The Semiarid Prairie Agricultural Research Centre in Swift Current has become a leader in climate change and carbon sequestration research. They have conducted climate change assessments for Saskatchewan, promoted development of computed simulations, produced reports on carbon sequestration, and related fields of tillage methods and grassland cultivation.

8.9 Prairie Adaptation Research Co-operative (PARC)

The goal of PARC is to solicit research proposals that address gaps in the knowledge of adaptation to climate change in the Prairie Provinces. These gaps have been identified in various scientific and stakeholder assessments, workshops, and elsewhere. Proposals will be accepted for research that will lead to a reduction of the identified gaps in our knowledge about adapting to climate variability and change on topics such as:

- agriculture
- energy production and demand
- fisheries
- forestry
- human health and safety
- infrastructure
- natural environment (both physical & biological)
- urban and rural settlements
- transportation
- recreation and tourism
- traditional lifestyles
- water resources on local and regional scales

Proposed research can address the issue on a sector or regional basis. Local scale case studies that include assessment of impacts also will be considered. Proposed adaptation and impacts research should address the gaps in such a way as to provide useful information for those who will use it in the development of adaptation options or strategies for the particular sector, community or region. Proposals should clearly demonstrate how this research could be translated into policy.

The proposed research should employ the most up-to-date techniques for examining sensitivities and vulnerabilities to climate changes and the development of adaptation strategies. No specific climate, economic or population scenarios will be supplied through PARC at this time. To ensure that the research results will be useful to stakeholders, researchers are encouraged to consult and work with stakeholders as applicable.

The current Call for Proposals covered the fiscal year ending March 31, 2001. It is possible that additional CCAF funding will be made available to PARC later in 2000. A second Call for Proposals would be issued at that time.

8.10 Environment Canada

Environment Canada is heavily involved in accumulating climate change data and conducting negotiations.

The Canada Country Study (CCS) is the first-ever national integrated assessment of the social, biological and economic impacts of climate variability and change in Canada. It involves climate experts from all levels of government, industry, academia and non-government organisations.

Environment Canada sponsors the Canadian Centre for Climate Modelling and Analysis, which recently completed a transient climate change experiment (Boer, et al., 1997) that takes the effects of historical and projected changes in greenhouse gas concentrations and sulfate aerosol distributions into account for the period between years 1850 and 2100. Selected data from these simulations will be contributed to the IPCC Data Distribution Centre to facilitate its use for climate impact studies.

8.11 Brandon Research Centre

The Brandon Research Centre has gathered information on methane production of beef cattle under range (or pasture) conditions. They concluded that cows grazing alfalfa-grass pastures consumed more dry matter, produced less methane, and lost less energy through methane release. The findings confirm that pasture type has an effect on methane production and feed efficiency. Related research completed by the Centre indicates that pasture finishing of beef cattle is feasible.

8.12 Soils and Crops Research and Development Centre

The Soils and Crops Research and Development Centre situated in Sainte-Foy, Quebec, has a mandate that includes providing technology and expertise in the area of integrated soil and crop management. They have two researchers that specialise in GHGs, Dr. E. van Bochove and G. Theriault. A recent study from the Centre measuring gas emissions from manure concluded that solid dairy cow manure produces the same amount of nitrous oxide per unit of nitrogen added to the soil as a mineral fertiliser. Researchers also developed a new technology to create an effective combination for nitrogen fixation between an alfalfa cultivator and a strain *Sinorhizobium meliloti.*

8.13 The Canadian University Program

The Canadian University Program is a stakeholder-instigated applied research programme that is creating a university-based network of experts in the climate sciences, biology and ecosystem analysis, technology and social sciences. This network has been designed to

facilitate integrated multidisciplinary research to provide information for Canadian decision-makers as they manage the climate change issue in the long term.

8.14 The Canadian Joint Implementation Pilot Initiative

This Initiative sponsors actions to reduce GHG emissions in other countries as part of the National Action Program. It encourages projects that are voluntary, enhance opportunities to transfer energy efficiency technologies to other countries, produce results in a cost-effective manner, are sustainable over the longer term, and have other environmental, social, and economic benefits. Such projects must contribute to net reductions in global emissions in a manner that can be measured and verified.

8.15 Canadian International Development Agency

The Canadian International Development Agency is the lead player in delivering Canada's official development assistant program. Environmental protection (including efforts to mitigate and adapt to climate change) is one of six priority areas addressed by CIDA. Dozens of CIDA aid projects with a climate change element have been initiated in developing countries.

8.16 World Climate Research Program

The World Climate Research Programme furthers scientific understanding of the climate system and climate processes. Within the program, Canadian scientists are working n the World Ocean Circulation Experiment and the Joint Global Ocean Flux Study to help improve understanding of ocean processes and to contribute to the development of ocean components of climate models. Canada is also participating in the Global Energy and Water Experiment by studying hydrological processes in the permafrost-saturated and largely snow-covered land of the Mackenzie River Basin.

8.17 Global Baseline Surface Radiation Network

Canada participates in the Global Baseline Surface Radiation Network, where ground-based measurements are taken continuously to improve our understanding of how much energy is entering Earth's atmosphere and how much is leaving it. Canadian measurements are taken at Bratt's lake in Saskatchewan and at the new stratospheric observatory at Eureka, in the Canadian Arctic.

8.17.1 Saskatchewan Soil Conservation Association

The Saskatchewan Soil Conservation Association is a non-profit, producer-based organisation whose mission is "to promote conservation production systems that improve the land for future generations." It holds a direct seeding conference and issues a newsletter, offers a farmer-to-farmer consulting service and membership benefits plan.

8.17.2 CSALE/CAEEDAC

The Centre for Studies in Agriculture, Law and the Environment (CSALE) is a centre for the study of agroecosystems at the University of Saskatchewan that includes faculty, staff and students. As a strategic partnership, CSALE integrates the life sciences and the social sciences to conduct research into environmental and legal issues related to agriculture. The Centre undertakes studies, provides education and develops policy options to enhance prairie and other agroecosystems. By collecting data on selective agroecosystems from world agriculture, CSALE is building on the work established on the Great Plains of North America. CSALE is currently developing a communication action plan that will disseminate this information to interested groups and individuals outside the University.

8.17.3 Canada-Saskatchewan Agri-Food Innovation Agreement

Canada-Saskatchewan Agri-Food Innovation Agreement (AFIA) contributes to the promotion and implementation of GHG reduction in areas including soil management, soil nutrient management, manure management, grazing strategies, feeding strategies, carbon storage, water management, agroforestry and food processing.

8.17.4 Canada-Saskatchewan Partnership Agreement on Water-Based Economic Development

Canada-Saskatchewan Partnership Agreement on Water-Based Economic Development (PAWBED) is aimed at alleviating water-related constraints to economic development and diversification opportunities in rural Saskatchewan. Funding is available to producers, communities, industry groups and individual entrepreneurs pursuing water dependent projects or agricultural processing initiatives in Saskatchewan. PAWBED contributes to the promotion and implementation of GHG reduction in areas such as water management and carbon storage.

8.17.5 The Prairie Ecozone Planning Framework

The Prairie Ecozone Planning Framework: An Ecosystemic Approach to the Activities of the Department of Environment. Environment Canada, Prairie and Northern Region, is undertaking an ecozone planning process to help it define the issues, knowledge gaps, and priorities on which it should be focusing its resources. Because of the size (approximately 5 million km2) and diversity of the Prairie and Northern Region, it is proposed that the planning be based on the region's major ecozones (prairies, boreal, cordillera, taiga, and arctic),

which extend across geopolitical boundaries (Alberta, Saskatchewan, Manitoba, and the Northwest Territories).

8.17.6 Canadian Plains Research Centre

Canadian Plains Studies at the University of Regina is an interdisciplinary graduate program that offers the student an opportunity to focus his or her studies on the prairie region and draw upon noted faculty members of various departments who are actively involved in research about the Canadian plains. Three current graduate projects have relevance to the climate change topic:

- Change and Adaptation in the Palliser Triangle (L. Dale)
- Human Impacts on Ecosystem Function in the Mixed Grassland Ecoregion. (T. Radenbaugh)
- History of Land Under Settlement: 1901 to 1991 (C. Thompson)

8.17.7 International Institute for Sustainable Development (IISD)

The IISD analyses the Great Plains area as a whole. The Institute aims to integrate all of their programmatic work in community adaptation, trade, business, communications, and measurement to prove that sustainable development is more than an abstract concept. The Institute combines concerns for the economic welfare of the inhabitants of the region with detailed criteria for sustainability. Indicators are offered for conservation, management, rehabilitation, biodiversity, common property, and global change. Then the environmental considerations can be weighed against equally vigorous criteria outlined for economic viability and social concerns.

8.17.8 Resources for the Future

The American organisation, Resources for the Future (RFF) launched its Climate Economics and Policy Program in October 1996 to increase understanding and knowledge of the complex issues that must be addressed to design appropriate domestic and international policies that are effective, reliable, and cost-efficient. It regularly publishes research papers and has over a dozen projects currently underway on carbon taxes, permits, modelling, economic incentives and other policy initiatives related to climate change. It also maintains the website Weathervane; a forum devoted to the discussion and debate of global climate policy[24].

8.17.9 The Land Institute

The Land Institute in Salina, Kansas is investigating the feasibility of growing perennial polycultures as a cash crop. There are considerable potential benefits for agriculture modelled on native prairie, composed of seed crops for human consumption. Ongoing research is being conducted investigating seed yields, overyielding, internal supply of fertility

[24] http://www.weathervane.rff.org/Default.htm

and management of weeds, pests and plant pathogens. One of the main challenges to the approach is breeding perennial grains, which is the research centres in Saskatchewan are well suited to doing. Two distinct approaches are possible with the modern development of perennial grains.

8.18 Prairie Farm Rehabilitation Administration

Prairie Farm Rehabilitation Administration (PFRA) is the contact for the Shelterbelt Program, Rural Water Development Program and Community Pasture Program. Publications:

- The effects of shelterbelts on cropping and tillage practices (Adobe pdf)
- Fruit-bearing shrubs for multi-use shelterbelts & orchards
- A guide to the status of improvement and development of woody plants at the Shelterbelt Centre.
- Sea-Buckthorn, a promising multi-purpose crop for Saskatchewan

8.19 McGill Centre for Climate and Global Change Research

The multidisciplinary McGill Centre for Climate and Global Change Research (C^2GCR) was created in March 1990. The main objectives of the Centre are to promote research on the interactive physical, biological, chemical and socio-economic processes that regulate the global environment.

8.20 The Intergovernmental Panel on Climate Change (IPCC)

The IPCC, established in 1988 by the World Meteorological Organisation (WMO) and the United Nations Environment Program (UNEP), Its main objective is to assess scientific, technical and socio-economic information relevant to the understanding of human induced climate change, potential impacts of climate change and options for mitigation and adaptation. The IPCC has completed two assessment reports, developed methodology guidelines for national greenhouse gas inventories, special reports and technical papers. Although it does not actually perform any scientific research itself, it provides a valuable service in assessing and disseminating what is known and, based on that knowledge, advises the international community.

The IPCC consists of three working groups:

- Working Group I addresses issues on the science of climate change
- Working Group II assesses the impacts of climate change
- Working Group III examines inter-disciplinary issues

Working Group III has established a Technical Support Unit to co-ordinate the group's activities. The Canadian leads for each of the IPCC Working Groups co-ordinate Canadians' participation in the activities of their Working Groups through networks of experts within and outside the government. These experts from government departments, industry, Egos, and

academia are involved in the peer and government review processes, and many have been asked by lead authors to contribute to the IPCC reports.

SECTION IV

GREENHOUSE GAS EMISSIONS IN SASKATCHEWAN AND POLICY OPTIONS FOR ABATEMENT

9 Introduction to GHG emissions

9.1 Greenhouse Gases

Greenhouse Gases (GHGs) trap the sun's heat near the earth, warming the surface. Without the greenhouse effect, the earth's average temperature would be -18°C instead of 15°C. An increase in GHG emissions disturbs the natural balance and causes climate change, which provides a significant risk for the global environment and the human economy.

Anthropogenic emissions refer to the release of GHGs into the atmosphere as a result of human activity. Canada contributes 1.8% of net global anthropogenic GHG emissions, 80% of which is carbon dioxide (CO_2) emissions. Canada is the second highest per capita producer of GHG emissions among major industrialised nations. This is due to the extreme nature of the climate and large distances between population centres. Our reliance on heating and transportation carries an accompanying increase in energy consumption.

The agriculture sector accounts for only 4% of national CO_2 emissions. Agricultural practices, chemical processes, and fertiliser production and consumption contribute more to methane and nitrous oxide emissions.

- Nitrous oxide (N_20) accounts for 5% of Canada's emissions[25]; 60% is from agriculture
- Methane (CH_4) accounts for 25% Canada's emissions; 13% is from agriculture

While the extent of human influence on climate change is uncertain and hotly debated, most scientists agree that anthropogenic emissions have made a discernible contribution to recent global warming. More important is the fact that human society will be seriously affected by climate change. Extreme weather could affect agriculture in the prairie region in many ways. There may be a sudden increase in demand for product in the event that another agricultural region in the world is destroyed by such an event. However, in another scenario, the region could fall prey to such an event itself. More extreme weather events

[25] measured on a CO_2 equivalent basis

are predicted for the Prairies, and the agricultural industry is particularly vulnerable—in the event of disaster, a producer cannot replace the year's crop the way a corporation could build a new warehouse or relocate an office.

9.2 Kyoto

The Kyoto Protocol to the United Nations Framework Convention on Climate Change was adopted at the third session of the Conference of the Parties (COP-3) in December 1997. If ratified, it contains legally binding emissions targets for Annex I (developed) countries for the post-2000 period. Canada's target is to reduce its GHG emissions to 6 percent below 1990 levels by the 2008-2012 time frame. This target would require a nation-wide emissions reduction by 2008 - 2012 of approximately 25%, from a "business as usual" scenario.

The Kyoto Protocol will only enter into force and become legally binding when at least 55 countries, including developed countries accounting for at least 55% of developed country emissions, have ratified. So far, only 14 countries—all from the developing world—have ratified the Protocol.

9.3 The Issue Tables

The Issue Tables, which involved over 450 individuals, were drawn from a broad cross section of government, industry, the academic community, environmental groups, scientists and non-governmental organisations. Issue Tables examined the impacts, costs and benefits of implementing the Kyoto Protocol and analysed the various options to reduce GHG emissions and meet the climate change challenge. Each Table was responsible for research and analysis, and the development of reports on their specific sector or issue:

The sixteen Tables are:

- Analysis and Modelling works closely with all the Issue Tables to ensure they have the necessary analytical and modelling resources, they strive to maintain consistency, comparability of the analysis of various measures/options, and address any emerging analytical issues.
- Transportation Considerable fuel combustion is generated by machinery operating during the production of agriculture, and in the transport of agricultural goods to market centres. These emissions are analysed within the transportation and energy categories.
- Electricity is grappling with the need to turn from low-cost technologies to higher cost options that reduce emissions. This may result in higher costs for the consumers, which would effect the operating expenses of fangs.
- Kyoto Mechanisms conveys Canada's negotiating position on international emissions trading, Clean Development Mechanism (CDM) and Joint Implementation (JI). (The Table did not address emissions trading issues specific to a potential Canadian system).
- Technology helps advance climate change solutions and bring them to market.
- Credit for Early Action was established because many sectors of the Canadian economy will be more likely to undertake voluntary emission reductions today if they are assured that those actions will be credited against any future obligations. The group intends to ensure that credited reductions are measurable, verifiable and will be credited in the future.
- Public Education and Outreach is essential if Canadians are to understand what climate change means to them, and if they are to take action to reduce personal greenhouse gas emissions. Outreach is also critical in building public support for broader policies and actions that will be put in place as governments and businesses move to address climate change.
- Buildings has a strong linkage with the Agriculture Table (among others) in order to consider renewable sources of energy to service rural properties and remote communities where costs of conventional energy make renewable energy a cost-efficient choice.
- Industry's aim has been to find ways to reduce GHG emissions while maintaining a vibrant and healthy Canadian economy. It has cautioned against adopting prohibitively expensive technology.
- The Forest Sector collaborates closely with the Agriculture and Sinks tables in developing a strategy for carbon sequestration.

- Enhanced Voluntary Action focuses on voluntary actions by industries, commercial organisations and institutions and will work with other Tables to address voluntary actions by consumers and the public at large. Part of its portfolio includes the Voluntary Challenge and Registry. As voluntary mechanisms are an excellent tool that can be recommended by other Tables, effective communications linkages between this and most other Tables is very important.
- Municipalities encourage local communities to undertake a sustained effort to reduce GHG emissions, with a 20 percent reduction as the ultimate goal.
- Science and Adaptation has the mandate to examine measures related to climate system research, monitoring, impacts and adaptation. The group has made links with the Sinks, Forestry and Agriculture Tables, primarily in terms of key science issues that need to be addressed.
- Tradable Permits explores the potential contribution of mandatory domestic emissions trading systems towards achieving a substantial reduction in greenhouse gas emissions in Canada. Clearly, this has a direct link to soil carbon sequestration anti the possibility of economic benefit through a carbon emission trading system.
- The Agriculture and Agri-Food Table's suggested measures focus on improving scientific understanding of N2O and CH4. One priority is to refine estimates of nitrous oxide emissions. The livestock sector has critical implications as the fastest source of methane and nitrous oxide and will require special attention.
- The Sinks Table's main mandate is to provide technical input and advice to governments to ensure that the necessary information and analyses are available to support a decision regarding the ratification and implementation of the Kyoto Protocol as it relates to sinks.

10 Tables of Relevance to Saskatchewan Agriculture

10.1 Energy Sector

GHG emissions from on-farm fuel combustion for tractors, combines etc. are usually included within the "energy sector" rather than under the "agriculture sector"[26]. In the energy sector, fuel combustion emissions are divided into the following categories:

- energy industries
- manufacturing
- transportation (with grain transportation being included in the "trucking" or "railway" sub-sectors and combines and tractors being included in the "off-road" sub-sector);
- residential
- commercial and institutional
- other

[26] This is an important classification to remember. For accounting and policy purposes, the agriculture sector falls under several different "sectors": Energy (transportation - off road vehicles for fuel use of tractors and combines); energy (transportation - trucks or rail for grain transportation); agriculture for soils and animal production, land, land use change and forestry for agroforestry issues etc.

Improving access to the federal government energy market is a key objective of NRCan's Renewable Energy Strategy. To this end, NRCan and Environment Canada have signed letters of intent for green power pilot projects with Ontario Hydro. Discussions with Alberta utilities and with Prince Edward Island are moving ahead. Green power is electricity generated from renewable energy sources that do not contribute to greenhouse gas emissions and have limited environmental impacts. These pilot projects will demonstrate the feasibility of broader applications of government green power purchases as a means of reducing greenhouse gas emissions and stimulating the renewable energy industry. NRCan and Environment Canada are working to expand federal and provincial involvement in the purchase of green power.

A cogeneration, or combined heat and power (CHP) system produces heat that is used both to generate electrical power and steam (or another hot gas) for industrial processing and district heating and cooling. The combination of highly efficient energy usage in the form of electrical power and steam can result in system thermal efficiencies of 80 percent and higher, compared to efficiencies of 30 to 40 percent at most power plants.

Biomass: When used for generating electricity, biomass is typically burned to transform water into steam, which is consequently used to drive a turbine and attached generator. Biomass can also be used for "co-firing," through which small amounts of biomass (5-15% by heat content), including wood chips and agricultural grasses, are combusted with coal in traditional coal fired generating units. This practice reduces the quantity of coal consumed, and thus results in lower levels of polluting emissions.

The transportation of crops and use of vehicles on farms is not included in the accounting for the agriculture sector. This makes the total emissions attributed to the industry deceptively small. However, it also means that changes within the sector will have far-reaching consequences upstream and downstream. Should Canadian agriculture moved to a more diversified, low-impact model geared to regional consumption, associated transport emissions could drop dramatically (along with transport costs for the producer).

Within the transportation sector, the heavy-duty diesel vehicle category includes vehicles rated at more than 3900 kg. Heavy-duty diesel vehicles have high fuel-consumption ratios and drive long distances. GHG trends associated with this segment of road transport are closely linked with those of Canadian trucking activity in which has been growing substantially, especially in Saskatchewan with the abandonment of rail lines. Diesel vehicles have higher emission rates than gasoline.

10.2 Technology

The research arm of NRCan is CANMET Energy Technology Centre (CETC), which has published a variety of reports on transportation and building energy efficiency technology[27]. Another public source for technology development is NSERC, which will invest $550 million in natural science and engineering research over the 2000-2001 funding period.

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[27] Many are available on the web at www.nrcan.gc.ca/es/etb/cetc/etcframe.htm

A great deal of North American technological innovation comes from the private sector. There exists a growing body of options that producers can draw on in planning their operations. John Deere is manufacturing equipment for precision farming, as is Cultiva and Giannotti Technological Services. Precision farming can help reduce emissions by providing geographical information that allows farmers to only distribute chemicals where needed.

10.3 Land Use Change and Forestry

Land use can be organised into four sections, each of which pertains to a broad category of GHG-producing/sequestering activities:

- Forestry (e.g., afforestation, plantation etc.);
- Agricultural Soils (e.g., soil conservation, productivity improvement);
- Livestock Management (e.g., livestock digestion, livestock manure management);
- Other Land Management Activities (e.g., land flooding, wetland drainage).

Open burning of vegetation, such as field burning of agricultural crop residues, releases all three GHGs, as well as other less important GHGs. Anthropogenic emissions activities that use or change land affect the amount of biomass in existing stocks and generally result in a loss of soil carbon.

- forestry
- agroforestry
- abandonment of croplands, pastures, or other managed lands
- clearing forests for agricultural use

10.4 Agriculture

Many agricultural activities result in emissions of GHGs. The processes that produce emissions are mainly enteric fermentation of domestic animals, manure and fertiliser management practices, and cropping practices that result in a release of GHG from the soil.

In general, Canadian agriculture operates in global markets with very narrow margins and with little ability to pass additional costs on to consumers. Given these limitations, the most viable means of achieving reduction in agricultural net GHG emissions is to create and to promote technologies that increase profitability and that can be voluntarily adopted.

The technologies that showed some verifiable low-cost reduction in GHG emissions involved carbon sinks that are currently not part of the Kyoto Protocol.

- increased zero tillage
- reduced summerfallow
- improved grazing strategies
- conversion of cropland to wetland and wildlife habitats
- agroforestry

- shelterbelts
- strawboard and other fibre manufacture

Because Canada is committed to GHG reduction regardless of Kyoto acceptance, these technologies can be promoted. However, further investments in research and development are needed to develop and to scale up internationally acceptable measurement and verification systems to the national level.

Other areas showed promise to reduce GHG emissions including crop nutrient management, livestock nutrient management, manure management and biofuels. While some aspects of the technologies are documented, in each of these areas there was uncertainty about the effects of specific technologies or more important, the best technologies to employ.

The agricultural sector has adopted technologies that have reduced GHG emissions for other environmental and economic reasons. If the agricultural sector has the incentive to reduce net GHG emissions, history suggests that producers would respond, find and adopt technologies that further reduce net GHG emissions. However, policies cannot require monitoring and verification of individual actions, nor can they involve large increases in the cost of production. The sheer number of farmers and the complexity of the systems make the monitoring and verification of individual actions very difficult and expensive.

Recommendation 1. Governments should provide resources to extend the knowledge base and foster the adoption of proven technologies. For example, governments should work with the industry to encourage the adoption of improved grazing management systems, feeding strategies, and zero tillage cropping systems.
Recommendation 2. In recognition of the public benefits where cost-effective technologies are well known, and an economic incentive is required for their adoption, governments should provide public incentives for the adoption of GHG-reducing technologies. These public incentives would stay in place until markets for emission reductions in the agricultural sector are established. For example, governments should work with the industry to develop financial incentives for the planting of shelterbelts.
Recommendation 3. The federal government should continue to insist on the inclusion of soil, forestry and industrial sinks in the international protocol and to ensure that the guidelines of the Intergovernmental Panel on Climate Change (IPCC) reflect Canadian conditions.
Recommendation 4. Governments should create research funds managed by the agricultural sector to assist in research and development of applied technologies for GHG reduction.
Recommendation 5. Governments should provide public resources to support basic research activities for net GHG reduction particularly in the areas of crop nutrient management, livestock nutrient management, manure management, carbon sequestration, and biofuels.
Recommendation 6. As part of a national strategy, governments should work with the agricultural sector to refine national inventory, measurement and verification systems for net GHG emissions and to reflect improvements in technology. Monitoring should include the

collection of more accurate raw data and the refinement of analytical models that can be used to manage and to assess the effectiveness of GHG-reduction policies.
Recommendation 7. As part of the national process, where possible, GHG emission trends in all sectors of agriculture in all provinces should be monitored and published.
Recommendation 8. Governments should work with the agricultural sector to develop targets for the reduction of GHG emissions along with incentives for meeting the targets.
Recommendation 9. Governments should assist the agricultural sector in the development and refinement of best management practices for the reduction of GHG emissions.
Recommendation 10. Governments should provide resources to assist policy research, market research, legal research and other public infrastructure to facilitate the development of trading mechanisms that reward reductions in net agricultural GHG emissions.
Recommendation 11. Governments should co-operate with private sector partners to develop a strategy that will enhance the agricultural sector's ability to adapt to climate change using sustainable farming systems.

10.5 The Sinks Table

Agricultural soil sequestration could offer crop producers greater revenue, and potentially lower input costs resulting from lower fuel use, as well as more efficient use of fertilisers. The overall impact of agricultural soils conservation practices on the environment is a healthier, more productive soil that is less subject to wind or water erosion, and more sustainable for agriculture systems and the environment they rely on.

Recommendation 2.1: relevant government departments should encourage their scientists and technical experts to undertake the research priorities identified in close collaboration with peers within the international community, and to use expertise appropriately in future negotiations related to carbon sinks within the context of the Kyoto Protocol.
Recommendation 3.1: an afforestation program to plant about 50,000 ha using fast-growing tree species should be implemented immediately as a category 1 measure.
Recommendation 3.2: afforestation programs to plant about 800,000 ha in block plantations and shelterbelts using traditional tree species should be implemented immediately as part of category 1.
Recommendation 3.3: policies to reduce deforestation should be part of Canada's post-2000 strategy (category 2) since emissions from deforestation from 2008-2012 must be added to Canada's target.
Recommendation 3.4: policies to encourage modification of reforestation methods to increase carbon sequestration on areas reforested since 1990 should be considered for inclusion in a post-2000 strategy (category 2).
Recommendation 3.5: policies should be put in place to promote activities in the managed forest that enhance carbon sequestration.
Recommendation 3.6: there is a high priority to continue to improve our understanding of the causes, location and extent of deforestation, and ways to reduce its impact.

Recommendation 3.7: there is a very high priority to determine the implications for Canada of including the managed forest and storage of carbon in forest products in the Protocol.
Recommendation 3.8: investigate the carbon sequestration and energy-saving impacts of urban forestry.
Recommendation 3.9: improve information on tree growth and yield, and changes in all carbon pools over time. Recommendation 3.10: determine carbon sequestration impact and costs of forest management activities on forest carbon pools over time.
Recommendation 3.11: improve information on the impact and cost of actions to modify carbon storage of carbon in forest product carbon pools, and their links to on-site carbon storage in all pools over time.
Recommendation 3.12: determine the potential effect of future climate change on predictions of carbon sequestration through activities proposed in recommendations 3.1 to 3.5.
Recommendation 3.13: governments should clearly state ownership policies regarding ownership of carbon sequestered.
Recommendation 3.14: improve information on the economic incentives needed for afforestation to take place.
Recommendation 4.1: conservation practices on cropland, pasture management, conversion of marginal cropland to perennial grass, and wetland restoration strategies should be considered further as potential policy development, in particular to build regional or provincial alliances, could commence in 2000.
Recommendation 4.2: all programs that directly or indirectly encourage carbon sequestration in agricultural soils should be maintained. Before existing extension programs are eliminated, they should be audited to determine if they are valuable in sequestering carbon.
Recommendation 4.3: the linkage of the wetland restoration with the conservation practices on cropland; pasture management and conversion of marginal cropland to perennial grass strategies should be taken into account.
Recommendation 4.4: the implementation of the strategies should be on a national basis, recognising that the available agricultural land base and climate in each province or region will limit the contribution to the soil carbon sink. Program funding could be on the basis of potential for carbon sequestration or number of hectares.
Recommendation 4.5: the federal and provincial governments should review all existing policies, which could affect the soil carbon sink enhancement strategies.
Recommendation 4.6: conduct research on nitrous oxide and methane emissions related to the four strategies noted above. Determine whether there are additional emission reductions or lower net carbon sequestration resulting from the effects of the five strategies on all greenhouse gases. Include fuel use, and nutrient management effects.
Recommendation 4.7: determine and refine new equilibrium levels and the carbon sequestration potential resulting from the four strategies.
Recommendation 4.8: conduct research to evaluate the economic benefits of each strategy, and identify practices that best fit each agricultural region of Canada.
Recommendation 4.9: governments should clearly state ownership policies regarding ownership of carbon sequestered in agricultural soils.
Recommendation 5.1: a steering committee composed of governments' representatives and stakeholders should be established and provided with adequate commitment and funding, to take responsibility for carrying through with implementing the forest C accounting system.

Such a committee should ensure that the reporting system employs methods and models that are meeting the requirements of the verification process, once defined by the international negotiations.
Recommendation 5.2: a steering committee composed of governments' representatives and stakeholders should be established and provided with adequate commitment and funding, to co-ordinate the development and implementation of the agricultural soils carbon stocks measurement, monitoring and verification framework.
Recommendation 6.1: continue to consider wetlands as a potential Kyoto sink, in particular through the organisation and co-ordination of science and policies relevant to such sinks.
Recommendation 6.2: develop a central focus for related research in Canada to properly assess, through focused workshops, the current state of knowledge and research priorities relevant to wetlands management as potential carbon sinks. One option for achieving this goal is to establish a wetlands research node under the BIOCAP program of Canadian universities[28].

11 Canada's National Plan

11.1 General Policy Options

Mitigation (emission reduction) can be achieved through:
- use of alternative sources such as solar and wind power
- use of ethanol and other renewable fuels;
- building the organic matter in the soils;
- reforestation;
- "Reduce and recycle" options.

Adaptation generally refers to actions required to achieve adjustments to future changes in the global climate, such as changes in average conditions and increases in the frequency and magnitude of weather events such as drought, floods and blizzards[29]. In effect, because adaptation actions are designed to alleviate a particular impact on a specific region or area, adaptation generally yields more local benefits. Adaptation works as an effective complement to mitigation actions: adaptation in anticipation of climate change ought to reduce the vulnerability of natural and managed ecosystems. Strategic directions for adaptation activities include:

- Enhancing communications and information networks involving the private sector, governments at all levels, the academic research community, and non- governmental organisations;
- Identifying regions and economic sectors most sensitive and vulnerable to the impacts of climate change;
- Determining appropriate adaptation responses, by integrating factors related to environmental and economic impacts and social acceptability;

[28] http://www.nccp.ca/html/tables/pdf/options/Sinks_OR-Sep-23-1999_en.pdf
[29] Saskggrn: http://www.eru.uregina.ca/saskggrn/documents/SKMar99news.html

- Improving environmental management and decision-making by incorporating possible climate change and variability impacts into the planning and decision process for all major projects and government programs;
- Identifying where developing new or modified technology would be required.

We need to recognise that there is a large array of actions that have value for both adaptation and mitigation. In agriculture, for example, conservation tillage increases the organic matter in the soil relative to conventional tillage, increases the moisture available for storage in the plant-rooting zone and reduces soil temperature. From the standpoint of increased organic matter in the soil this measure would mitigate emissions, but perhaps more significant is the adaptive value if conditions are warmer and drier.

The Government of Canada accepts that renewable energy sources — such as hydro, biomass, wind, solar, waste and earth energy — can play an important role in Canada's efforts to address climate change while contributing to economic growth and job creation. Renewable energy sources currently supply 18 per cent of Canada's total primary energy supply, with large-scale hydroelectricity accounting for most of this supply. Renewable energy sources remain largely untapped.

The potential for using energy from biomass is significant. In addition to wood and agricultural wastes, some types of industrial and municipal solid wastes are suitable for use as energy sources. Other crops, commonly called energy crops, are cultivated exclusively for use as sources of energy. Internationally, animal wastes are also a popular option, both for the generation of biogas and for direct combustion.

Ethanol is the only fuel of significance in North America to be produced from renewable resources. Ethanol is currently produced from grains: wheat and barley in Western Canada and corn in Ontario. Co-products of from Canadian ethanol facilities are often fed to livestock (as distillers grains), or as human dietary materials. The growth of grain, from which ethanol is produced, uses carbon dioxide from the atmosphere, and cycles it through the transportation fuel system back to the atmosphere. The cycling of carbon is an effective method of harnessing the sun's energy, turning it into a renewable fuel for automobiles. Ethanol reduces pollution because it is a cleaner burning fuel than gasoline. In addition to being used as a motor fuel, it is the raw material for hundreds of chemicals used in foods, medicines and pharmaceuticals.

Many businesses have researched ethanol production using waste materials such as straw, paper, or wood chips, but technologies for the conversion of this woody biomass to ethanol has proven more costly than the traditional use of grains as a feed stock. However, a new Canadian process has shown commercial promise, and a new development agreement between Iogen Corp and PetroCanada will facilitate the demonstration of the technology at Iogen's existing site before the next millennium[30].

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[30] http://www.agr.ca/policy/environment/sustainability/stewardship/climate_change/ethanol/ethanolbackinfo.html

Taxes, regulatory standards, tradable emissions permits, information programs, voluntary programs, and the phase-out of counterproductive subsidies can all play a role. While the government of Canada has made several changes to its tax laws that support climate change, renewable energy and energy conservation efforts, *none of the alterations are targeted at producers interested in adopting management methods reducing emissions.* For example, the 1996 federal Budget improved access to financing for renewable energy and energy efficiency by expanding the eligibility for flow-through shares to include pre-production costs pertaining to eligible investments in the renewable energy industry. Companies undertaking energy efficiency and renewable energy investments can claim the accelerated tax write-offs association with these investments against income from all sources. Pre-production costs would be 100% deductible and now could be renounced to shareholders under a flow-through share agreement.

11.2 Aspects of the National Policy

11.2.1 The National Round Table on the Environment and the Economy

The National Round Table on the Environment and the Economy is an independent agency of the federal government. Its main goal is to provide objective views and information regarding the nature and scope of national debate on issues that focus on the environment and the economy. The NRTEE is composed of a Chair and up to 24 members who are appointed by the Prime Minister from a variety of regions and sectors of Canadian society, including business, labour, academia, environmental organisations and First Nations.

11.2.2 Joint implementation

Many studies have examined the likely effects of climate change on agriculture both in Canada and elsewhere. The global situation appears not to be very reassuring. Developing countries are likely to have considerably more difficulty adapting to climate change due to inferior technology and less available capital[31].

The federal government works with provincial and territorial governments, industry, and environmental groups to operate the Canadian Joint Implementation Pilot. The Initiative encourages projects that are voluntary, enhance opportunities to transfer energy efficiency technologies to other countries, produce results in a cost-effective manner, are sustainable over the longer term, and have other environmental, social, and economic benefits. Key objectives of the Canadian initiative include:

- contributing to global efforts to reduce net emissions of greenhouse gases through voluntary partnerships between Canadian and foreign entities
- encouraging private-sector initiatives to develop and disseminate technologies and build capacities with other countries
- testing and evaluating methodologies for initiating joint implementation

[31] http://www.epa.gov/globalwarming/actions/solar/biomass/index.html

- gaining early, practical experience that can be used to develop a longer-term joint implementation program both domestically and internationally

Project results are recorded, monitored, and publicly reported on a regular basis through the Voluntary Registry.

11.2.3 Clean Development Mechanism

Canadian bilateral aid aims to increase the capacity of developing countries to plan and implement economically and environmentally sustainable development activities. Climate change is being addressed through financing and supporting projects that provide increased access to renewable energy resources, energy efficiency opportunities, and the conservation of carbon sinks.

By contributing to multilateral bodies such as the Global Environment Facility, the United Nations Environment Program and the World Bank, Canada makes significant investments in air quality programs in the developing world. In addition, Canada has helped finance the participation of developing nations in international climate bodies such as the Intergovernmental Panel on Climate Change, the World Meteorological Organisation and the Secretariat of the Framework Convention on Climate Change[32].

11.2.4 Voluntary Action

Voluntary actions have been and integral part of Canada's approach to reducing greenhouse gas emissions since the mid-1990's. The Voluntary Challenge Registry was created to encourage public and private sector organisations to voluntarily limit their GHGs. Since the introduction, almost 800 organisations have registered. A major challenge in improving voluntary action is "to enhance the level of uptake and performance"—or accelerating the country's natural inclinations.

[32] http://www.ec.gc.ca/climate/resource/cnapcc/c3part05.html#international

Saskatchewan Enrolment in the VCR

Akzo Nobel Chemicals Ltd.
Denro Management Ltd
Enbridge Pipelines (Saskatchewan) Inc
Federated Co-operatives Ltd
Government of Saskatchewan
IMC Kallium Canada Ltd
Landwest School Division
Moose Jaw Roman Catholic Separate School Division
Potash Corporation of Saskatchewan Inc.
Regina School Division
Regina, City of
Saskatoon Central School Division
Saskatoon (West) School Division
SaskEnergy
SaskPower
South East Health District
University of Regina
University of Saskatchewan

11.2.5 Emissions Trading

Emissions Trading is an incentive-based alternative to command-and-control regulation of emissions. The sources of a particular pollutant are given permits to release a specified number of tons of the pollutant. A government or trading agency issues only a limited number of permits consistent with the desired level of emissions. The owners of the permits may keep them and release the pollutants, or reduce their emissions and sell the permits. The fact that the permits have value as an item to be sold or traded gives the owner an incentive to reduce their emissions.
The Greenhouse Gas Emission Trading Pilot is designed to:

- provide all participants with practical experience in emission reduction trading
- assess environmental and economic benefits of emission reduction trading;
- test and evaluate the technical, administrative and legal elements of an emission reduction trading system
- maximise involvement of the private sector by emphasising the use of business principles to achieve environmental and economic objectives
- encourage identification and joint investment in GHG emission reduction,
- avoidance and/or sequestration activities
- help build the foundation for a possible future emission reduction trading system

During the Pilot, buyers and sellers of emission reductions submit documentation on traded projects to a stakeholder committee for review. If the emission reductions satisfy the

requirements of the GERT Pilot, they are registered and will be eligible for recognition against future compliance obligations.

Pilot projects can be located anywhere, but either the buyer or the seller must be Canadian. If the project is located outside of Canada, the buyer must report the reduction only in Canada. As well, if either the buyer or seller is outside the country, use of the emission reduction for compliance purposes will depend on future international trading agreements signed by Canada.

11.2.6 Baseline Protection Initiative

On January 12, 2000 the joint Federal/Provincial Ministers of Energy and Environment Ministers officially announced the Baseline Protection Initiative. Baseline Protection allows businesses and institutions to reconstruct their emissions baselines to include reductions in emissions achieved through investment in early actions. To participate, businesses and institutions have been invited to register their actions with VCR Inc. (ÉcoGESte for organisations whose operations are in Québec).

11.2.7 Biodiversity

The Biodiversity Convention Office co-ordinates Canadian involvement in any negotiations leading to the United Nations Convention on Biological Diversity. Following ratification of the Convention, attention shifted to development of a Canadian response to the Convention. Under the guidance of the BCO, a federal-provincial-territorial working group began developing the Canadian Biodiversity Strategy. This was completed in 1996, and has since become a guide for all jurisdictions in implementing the Convention in Canada.

11.2.8 Federal Renewable Energy Strategy — New Tax Incentives

In October 1996, the Minister of Natural Resources released the Renewable Energy Strategy Creating a New Momentum. This strategy is a blueprint for co-operative, market-based action with a broad range of stakeholders to support the development of a more dynamic and self-sustaining renewable energy industry in Canada. The strategy has three pillars: enhancing investment conditions, supporting technology research and development, and developing markets for renewable energy technologies.

As announced in the 1996 Federal Budget, the Government is introducing legislation that, among other things, will extend the use of flow-through share financing currently available to non-renewable energy and mining projects. A new Canadian Renewable and Conservation Expenses (CRCE) category is being created to this end. The Renewable Energy community, NRCan and Finance have worked together to define CRCE.

11.3 Initiatives that Build Infrastructure

The Saskatchewan Pilot-Prairie Adaptation Outreach: Achieving a Broader Network. A pilot workshop funded by CCAP was held in Regina from March 1-2, 1999. The workshop's purpose was to engage resource sectors and provincial, regional and local

governments in Canada's Prairie provinces in a dialogue to develop an understanding of the climate change issue and the potential ramifications for current and future economic development, environmental health, human health and social security. A key objective was to build a knowledge base among participants who are in a position to take the information and engage Canadians through a variety of outreach methods including brochures, workshops, fairs, exhibitions and other educational opportunities.

Natural Capital: Views from Many Perspectives: was held on April 23, 1999, and sponsored by the Institute for Environmental Studies, University of Toronto, the Ecological Monitoring and Assessment Network (EMAN) and the World Bank. The workshop concentrated on integrating ecosystems thinking with economic theory.

Project Climate Change. Sponsored by the Saskatchewan Science Centre, and funded by the CCAP, the project consists of an interactive exhibit at the Centre, a mobile exhibit to travel to various venues across the province, travelling "toolkits", and public outreach programming.

The Great Plains International Data Network: Supporting Science on the Great Plains. The Great Plains International Data Network (GPIDN) was formed in 1993 to address basic data access and integration issues. More than 70% of the Plains' original grasslands have been converted to agricultural or other altered land uses. Although environmental researchers are concerned about losing further diversity of biological resources, residents of rural communities are concerned about protecting their economic stability and livelihoods. These differing, and sometimes opposing, concerns, combined with obstacles to sharing data and information, detract from progress toward solving issues. The Network aims to alleviate this situation.

CSALE modelling conferences: While a great deal of work on modelling projects has been conducted, the involved researchers now need to co-ordinate their efforts in order for the information to be applied effectively. In June 2000, the Centre for the Study of Agriculture, Law and the Environment organised a small workshop and brought together twenty researchers involved in climate change modelling to make short presentations on the systems with which they were familiar. A larger conference is intended for fall 2000.

IISD and IUCN have proposed the convening of a Standing Conference on Trade and Environment (SCTE). The Conference would be a forum for achieving coherence in environmental policy as it relates to trade. It would gather the key environmental actors with an interest in trade policy, review policy objectives and proposals, and seek to formulate practical recommendations, which could be introduced to the WTO and other policy forums. SCTE is would be a light structure, not a new organisation. Uniquely, it would gather intergovernmental organisations, secretariats, and key elements of civil society.

Environment Canada (EC) is planning to host workshops through the Prairie Ecosystem Planning Framework for each of these ecozones to obtain the assistance of other federal departments, the provinces and territories, universities, and other stakeholders in defining knowledge gaps and priority issues. It is proposed that the knowledge gaps and priority

issues be defined without limitations of jurisdiction or mandate. Once the gaps and priorities have been defined, the partners will determine the roles and responsibilities of the participants.

NRCan is hosting a conference on energy efficiency from October 10-12, 2000 at the Ottawa Conference Centre. Organised by the Office for Energy Efficiency, the conference will explore how reducing energy emissions can improve the bottom line for business. One group of sessions focuses on transportation, and there is an initiative being planned for university students to make poster-presentations related to energy efficiency.

Expo 2000 in Hanover, Germany is devoted entirely to the concept of sustainability. The theme is "Humanity—Nature—Technology". Demonstrations on agriculture aim to prove that sustainable food production can combine the best features of organic and conventional farming.

11.4 Area Studies

It is also useful to consider the impacts of climate change on the Great Plains area as a whole rather than limiting the scope of study to the Canadian prairies. The area directly south of the border has similar economic activity, population density, and concerns with export activity. Expanding the area of consideration promotes the use of an ecosystem approach, which is a holistic and integrative approach to solving the interlocking problems of poverty, environmental degradation, and disintegration of rural communities 33. Due to the national boundary running through the Great Plains, it also offers an opportunity for comparative analysis of different policy implementations and their impacts.

11.4.1 Palliser Triangle Climate Change Project

The Palliser Triangle is the driest region of the Canadian prairies, extending from southwestern Manitoba to southern Alberta. It often accounts for over half of Canada's agricultural production, despite a highly variable climate. However, future sustainable activities in parts of this region could be threatened by global climate change, which is expected to result in more frequent drought. To help prepare for these changes, the Geological Survey of Canada began a collaborative, multidisciplinary research project in 1991 to evaluate the impacts of climate on the critically important land and water resources of the Palliser Triangle. The project consists of three research components:

- developing high resolution records of past climatic and hydrologic changes
- improving understanding of the relationships between climate and landscape processes
- computer (GIS) analysis of landscape sensitivity[34].

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[33] 11 key Issues for Great Plains Sustainability. IISD. Accessed 6/16/00 at http://iisd.ca/agri/default.htm
[34] http://sts.gsc.nrcan.gc.ca/page1/clim/palliser/

11.5 Research on Adaptation

11.5.1 Selected Research from the Adaptation and Impacts Research Group

Koshida, G. and W. Avis, eds. 1998. The Canada Country Study: Climate Impacts and Adaptation - Volume VII: National Sectoral Volume (Downsview: Environment Canada, Environmental Adaptation Research Group) 620 pp.

Bein, P. and D. Rintoul, 1995. Precautionary Shadow Pricing of Greenhouse Gases under Business-as-usual Scenario (Victoria, British Columbia: BC Ministry of Transportation and Highways) Revised November 1996, 23 pp. ISBN 0-7726-3126-3

Burton, I. (1998) Adapt and Thrive - Disaster Mitigation = Climate Adaptation: Time to Rethink Canada's Climate Policy (Downsview: Environment Canada, Environmental Adaptation Research Group)

Burton, I. (1998) Adaptation to Climate Change: Compliance and Other Issues (Downsview: Environment Canada, Environmental Adaptation Research Group)

Chiotti, Q, D. Demeritt, D. Rothman, I. Burton. (1998) "The Cost of Climate Change in Canada: A preliminary assessment." Submitted to the Canadian Geographer special issue on Regional Perspectives of Environmental Change in the 20th Century.

Rivers, R., L. Mortsch, I. Burton. (1997) "The Economics of Climate Change: The Economics of a Water Adaptation Strategy" Paper presented to the Annual Conference of the Canadian Society for Ecological Economics, Hamilton 1997.

Burton, I. (1996) "The Evolution of Adaptation in Response to Climate Change" in Proceedings of 14th International Congress of Biometeorology 1-8 September 1996, Ljubljana, Slovenia, pp 44-52.

Burton, I., S. Cohen (1992) "Adapting to Global Warming: Regional Options" Theme paper for international conference on Impacts of Climatic Variations and Sustainable Development in Semi-Arid Regions, Brazil, Jan 27 - Feb 1, 1992.

Tyrchnewiez, A. and Q. Chiotti, 1997. "Agriculture and Climate Change: A Prairie Perspective" in Responding to Global Climate Change in the Prairies - Volume III of the Canada Country Study: Climate Impacts and Adaptation R. Herrington, B. Johnson and F. Hunter, eds. (Regina: Environment Canada, Atmospheric Environment Service)

Chiotti, Q., T. Johnston, B. Smit and B. Ebel: 1997. "Agricultural Response to Climate Change: a preliminary investigation of farm-level adaptation in southern Alberta" in Agricultural Restructuring and Sustainability: A Geographical Perspective B. Ilbery, Q. Chiotti and T. Rickard, eds. (Wallingford: CAB International) 201-218

Etkin, D.A.: 1995. "Beyond the Year 2000, More Tornadoes in Western Canada? Implications from the Historical Record" J. Natural Hazards 12:19-27

Koshida, G., 1992. "About Drought in Canada" CLI-01-92 (Downsview: Environment Canada)

Koshida, G. and L. Mortsch, 1991. "Climate Change and water level impacts on wetlands: a bibliography" CLI-1-91 (Downsview: Environment Canada).

Maarouf, A.R., 1999. Threat of climatic change, variability and extremes to health and safety in Canada. Preprints (CD-ROM), 15th International Congress of Biometeorology, Sydney, Australia (Sydney: Macquarie University).

Skinner, W.R., and J.A. Majorowicz, 1999. "Regional climatic warming and associated twentieth century land-cover changes in north-western North America" Climate Research, 12, 39-52.

Gullett, D.W., W.R. Skinner and L. Vincent, 1992. "Development of an historical Canadian climate database for temperature and other climate elements" Climatological Bulletin, 26(2), 125- 131.

11.5.2 Selected Research from Canadian Agri-Food Research Council

- Climate, water and crop growth and adaptation for the semiarid prairies.
- International Agri-Food Trade and Its Domestic Impacts
- Economic analysis of farm level competitiveness with respect to inputs, cost of production and sustainability
- Economic Assessment of Environmental Policy Instruments for Agricultural Production
- Investigation on the purchase price of land and on the account of resource quality.
- Evaluation of poplars as an alternative crop.
- Woody crops for sustainable production on marginal lands
- Sustainable cropping systems, Three Hills site
- The development of decision making tools for use in crop management systems
- which improve soil and water quality and reduce soil gas emissions for Economic Assessment of Environmental Policy Instruments for Agricultural Production

11.5.3 Selected Research from the Prairie Adaptation Research Co-operative

Potential Impacts of Climate Change on Agriculture within the Canadian Prairies, V. Wittrock, November 1998, 10439-7D98

Climate and Fire Connections in the Western Canadian Boreal Forest, E. Wheaton, V. Wittrock, June 1998, 10441-3D98

Climate and Wetlands: Past Lessons and Future Possibilities (Abstract), E. Wheaton, June 1998 10441-2D98

12 Scientific Gaps and Issues

12.1 Models

General Circulation Models (GCMs) are computer depictions of the global climate system that simulate responses of climate to changing conditions such as the concentration of GHG's. They are based on science and simplify the complex climate system to a series of mathematical expressions. The three models commonly used by Canadian researchers are the Canadian Climate Change Second Generation GCM (CCC GCM II), the Geophysical Fluid Dynamics Laboratory (GFDL) and the Goddard Institute of Space Studies (GISS).

The most common scenario modelled is for an equivalent of doubling the pre-industrial atmospheric concentrations of carbon dioxide (2 times CO_2 levels), a condition expected to occur some time in the future if emissions continue on their present course (the "business as usual" scenario).

12.1.1 The CEEMA Model

Canadian Economic and Emissions Model for Agriculture is an integrated Agri-ecological economic modelling system developed at Agriculture and Agri-Food Canada that can be used to simultaneously assess the economic and greenhouse gas emission impacts of agricultural policies at regional and national levels. The model is a quantitative tool that can contribute to policy analysis related to Canada's climate change goals through analyses of changing agricultural economics and production practices relative to patterns of greenhouse gas emissions. CEEMA contributes to the promotion and implementation of greenhouse gas-reducing practices through soil management, soil nutrient management, manure management, grazing strategies, feeding strategies and carbon storage.

12.1.2 The CENTURY model

The CENTURY model accounts for several agricultural management practices including planting, fertiliser application, tillage, and grazing and organic-matter addition. Statistics Canada agricultural census data are used to obtain crop cover and percentage of conventional and no-tillage practised for census years. Yearly crop coverage from 1990 to 1996 was taken from Statistics Canada core data. Soil data were derived from the Canadian Soil Information System (CanSIS). Fertiliser consumption and conservation tillage information was derived from data and Agriculture and Agri-Food Canada studies. The practice of biomass burning has been decreasing significantly in the past few decades and has not been included in the model because it is assumed to be negligible. Manure addition and soil erosion were not integrated, as the model cannot handle such heterogeneous patterns. Neither does the CENTURY model take into account emissions from the liming of soils. Based on these inputs the CENTURY model was used to determine annual estimates for the period 1990 to 1996, with forecasts to 2010.

There is a large degree of uncertainty associated with the estimates provided by the CENTURY model. Comparisons of CENTURY outputs with field measurements suggest that further refinements would improve the reliability of the model in predicting soil carbon change in response to no-till practices in the prairies (McConkey, 1998). Despite this, the CENTURY model is considered more appropriate for estimating the rate of change of soil organic carbon in Canada than procedures from the IPCC Guidelines.

12.1.3 Climate Modelling Groups

The Environment Canada climate-modelling group at the University of Victoria has developed global ocean circulation and ice models and coupled them to their atmospheric global climate model. Two runs of this fully coupled model have been performed, each covering a period of 250 years. It is one of the few such experiments conducted anywhere in the world that features both transient greenhouse gas and sulphate aerosol forcing. Results are expected to show that the simulated global warming between 1900 and the present are in general agreement with actual observations.

The Climate Research Network of Environment Canada has for the first time run a regional climate model, a sophisticated atmospheric model which has greater detail than the global models usually run. This regional model has been used to conduct two five-year climate simulations for western Canada, using both present-day and doubled levels of carbon dioxide. The greater level of detail in these models will be valuable to many sectors of the economy that may be impacted by climate change, such as forestry, agriculture and the insurance industry.

Analysis of the results of these new regional model runs, due in 1997, will yield an improved assessment of the rate, magnitude and regional variation of climate change in Canada and will be published in scientific journals.

12.1.4 Modelling Improvements

Impacts modellers believe that improvements should enable impact assessment to more consistently and completely assess:

- other biologically mediated greenhouse gases and therefore alter the projected future relationship between anthropogenic emissions and atmospheric concentrations quantitatively
- direct and physiological effects of CO_2
- direct and indirect effects of climate and their interactions
- transient effects, particularly the relationship between the rate of climate change and responses of ecosystems
- feedback from the biosphere and changes to climate, through changes in land-surface physical characteristics, and through changes in ecosystems which may affect the fluxes of GHGs
- sensitivity of different systems to climate change
- standardised climate projections to identify the range of possible change, coupled with more consistent use of sensitivity analysis

- detection and monitoring of impacts of climate change where changes consistent with climate change have been observed to have taken place, e.g. retreating glaciers, changes in geographical areas affected by vector borne diseases, shifts in habitat
- uncertainties
- information regarding a long-term strategy of investment which balances resources for adaptation and mitigation[35]

NRCan's Canada Centre for Remote Sensing has developed a reliable way of computing surface radiation based on satellite measurements. It has also produced a five-year record of surface radiation for the globe. The computations and data set are widely used by Canadian and international climate modellers. The Canadian Climate Centre, the U.S. National Aeronautics and Space Administration (NASA), the European Centre for Medium-range Weather Forecasting, the National Center for Atmosphere Research, and several other research institutions are using this data set to evaluate GCMs. The retrieval methods will be used in NASA's Earth Observing System, the largest space program ever launched for studying the Earth's climate[36].

12.2 Data for Models

The data available for impact assessments includes...

12.2.1 Monitoring Canadian Vegetation from Satellites

The purpose of this program is to develop and demonstrate procedures for monitoring the seasonal development and carbon uptake by vegetation across the Canadian landmass. Vegetation strongly influences regional weather systems, as well as climate. In turn, weather affects vegetation through precipitation and energy regimes. Northern vegetation is a potentially significant carbon sink. Because of rapid seasonal changes (in some areas the growing season is less than eight weeks) and Canada's size, satellite technology is the only practical means of monitoring the countrywide development of vegetation, which is of considerable economic importance.

Satellites launched by other countries collect these data and transmit the information to ground stations. A computer system processes the data and then selects cloud-free portions to produce consistent cross-Canada composites. These are further processed to remove residual noise, and thus enhance the vegetation information. Special analytical procedures convert the satellite measurements into variables describing the status of vegetation during the period of interest. This monitoring process continues throughout the growing season, providing a comprehensive picture of the growth and development of the various vegetation types.

An advanced monitoring system (designed and built by a government-industry team) processes daily satellite data for all of Canada and produces cloud-free images every 10 days. Since the start of the 1993-growing season, the Manitoba Remote Sensing Centre,

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[35] http://ipcc-ddc.cru.uea.ac.uk/

[36] http://www.ccrs.nrcan.gc.ca/ccrs/tekrd/rd/apps/em/cchange/datastse.html

under an agreement with NRCan, has been operating this system with data received by ground stations in Prince Albert, Saskatchewan, and Halifax, Nova Scotia.

12.2.2 Regional Ecosystem Effects of Atmospheric Change

The Regional Ecosystem Effects of Atmospheric Change (REEAC) study focuses on the effects of atmospheric change in Canada by looking at regional ecosystems. The study is being conducted over an estimated two-year period in co-operation with the departments of Natural Resources, Agriculture and Fisheries and Oceans, as well as private sector partners.

The first stage of REEAC will involve developing regional climate change and UV-B scenarios that will describe expected levels of precipitation, temperature, UV radiation and other critical variables, using computer models and historical climate data. These scenarios will then be used to carry out a detailed assessment of the probable effects on regional water cycles and hydrographs across the country, followed by an evaluation of environmental, social and economic impacts and opportunities for adaptation.

12.2.3 National Soil Database

The National Soil Database NSDB is the set of computer readable files that contain soil, landscape, and climatic data for all of Canada. It serves as the national archive for land resources information that was collected by federal and provincial field surveys, or created by land data analysis projects.

The NSDB includes GIS coverage at a variety of scales, and the characteristics of each named soil series. The principal types of NSDB data holdings are as follows.

12.2.4 National Ecological Framework (EcoZones, EcoRegions, and EcoDistricts)

Coverage includes the entire landmass of Canada. Polygons are nested groupings of Soil Landscapes of Canada.

12.2.5 Soil Map of Canada / Land Potential DataBase (LPDB)

Coverage includes the entire landmass of Canada. Originally produced in the early 1980s, much of this information is outdated and better data is available.

12.2.6 Agroecological Resource Areas (ARAs)

Coverage includes most agricultural lands in Canada. Data includes capability for Agriculture and Forestry.

12.2.7 Program of Energy Research and Development (PERD)

The interdepartmental Program of Energy Research and Development (PERD), responsible to the Minister of NRCan, continues to co-ordinate and develop work under its new Task on

Energy and Climate Change. PERD will continue the necessary studies into the effects of the well-known greenhouse gases (carbon dioxide, methane and nitrous oxide). In addition, this research program is increasing the emphasis on studying the effects of aerosols (microscopic airborne particles, which tend to cool the atmosphere) and the role of water vapour and clouds, which may be influenced by the effects of greenhouse gases.

12.3 Research Related to Models

12.3.1 Selected Work from the Climate Research Network

Comer, N., P. M. Lafleur, et al: 1999. "A test of the Canadian Land Surface Scheme (CLASS) for a variety of wetland types." Atmosphere-Ocean: accepted.

Fyfe, J., G. Boer, et al: 1999. "The Arctic and Antarctic oscillations and their projected changes under global warming." Geophys. Res. Lett.: accepted.

Laprise, R., D. Caya, et al: 1998. "Climate and Climate Change in Western Canada as Simulated by the Canadian Regional Climate Model." Atmos.-Ocean 36(2): 119-167.

Lin, H., J. Derome: 1998. "A three-year lagged correlation between the North Atlantic Oscillation and winter conditions over the North Pacific and North America." Geop. Res. Let. 25: 2829-2832.

Verseghy, D. L.:1999. "The Canadian Land Surface Scheme (CLASS): 1987-1997." Atmosphere-Ocean: accepted.

Verseghy, D. L., I. R. Saunders, et al: 1999. "Application of the Canadian Land Surface Scheme (CLASS) to the simulation of energy and water fluxes over alpine tundra." Atmosphere-Ocean: accepted.

Vettoretti, G., W. R. Peltier, et al: 1998. "Simulations of mid-Holocene climate with an atmospheric general circulation model." J. Climate 11: 2607-2627.

12.4 Scientific Research Needs

- It is necessary to distinguish between short-term fluctuations and long-term trends in the climate record.
- The interactions among agricultural practices, climate and retained carbon are extremely complex and further analysis to avoid adverse impacts on other emissions.
- What will agriculture be like in a given changed climate?
- What are the correct values of climate parameters for assessments?
- What are the CO_2 fertilisation effects?

- Since climate change is likely to alter the hydrological regimes of the Prairie regions, it should be factored into water-resource planning and polices for the future-at least on a contingency basis
- What happens to the rate of photosynthesis over the longer term?
- How significant is the potential for crops to become more vulnerable to increased competition from weeds.
- Long-term studies are needed to better define the roles of short-term acclimation and long-term crop adjustments to higher CO2 levels.
- Response to different genotypes of the same crop
- Below ground processes (root systems and the soil)
- Litter characteristics and composition
- Carbon and nutrient allocation within the plant
- Yield quality
- Plant response to high-temperature stress
- Influence of lengthened growing season on plant development
- Differential effects due to changes is max / min temperatures
- Response to changing hydrological regimes & climate variability
- Temperature Effects on Soil Nutrients
- Hydrological effects on soil nutrients
- What will be the likely effect of CO_2 concentrations on soils
- What are the likely changes in the spread of insects and diseases?
- Are crop losses due to weeds, insects, and disease likely to increase?

12.5 Applied Research Needs

Four general categories of agriculture projects can be identified in relation to their impacts on the absorption or emissions of GHGs. They are:

12.5.1 Productivity Improvements

Agricultural productivity improvement projects have the objective of increasing unit agricultural production. As a result, the project may reduce the pressure on other land use forms, particularly forests and thereby preserve an existing GHG sink. However, in some cases, the higher productivity may result in an increase in GHG emissions from the agricultural activities due to methane emission from higher yielding varieties or higher use of energy and fertilisers. Estimating the net GHG impact of an agricultural productivity improvement project will require careful evaluation of both the positive and negative GHG impacts.

12.5.2 Soil conservation projects

Soil Conservation Projects have the objective of adjusting agricultural practices to reduce the loss and enhance the productivity of valuable topsoil. As a result, these projects may increase the uptake or reduce the production of GHGs namely CH_4 and N_2O. In many cases, soil conservation projects incorporate the use of specific tree species to stabilise soils, increase nitrogen fixation and improve soil fertility.

12.5.3 Soil Enhancement Projects

Soil enhancement projects have the specific objective of expanding specific tree species within the farming system to stabilise it, boost productivity and/or provide wood raw material or opportunities to expand the income base. This should also increase the store of carbon (and nitrogen) within the system.

12.5.4 Livestock Production Projects

Livestock production projects have the primary objective of either improving the productivity or increasing the production of the livestock sub-sector. The results of a livestock project can either increase or decrease the net GHG emission, primarily methane, depending on the objective of the project. If the objective of the project is to increase the productivity of the livestock sub-sector, the result may be a net decrease in GHG emissions. However, if the project simply increases the production of livestock, the result may be an increase in GHG emissions. An important category of agricultural improvement projects includes rice production and methane reduction projects.

12.6 Biogenetic Engineering, Crop Characteristics and Climate Change

Cold and heat tolerance and freezing resistance are important characteristics for almost all crops and are of crucial strategic importance to Canada. Freezing resistance has a significant bearing on yield stability and cold tolerance (particularly as it relates to the vigour of seedling growth) and has a major influence on yield potential. Parallel gene discovery programs in different systems will likely uncover novel and complementary avenues to engineering increased cold tolerance and increased frost resistance.

Resistance to disease is an important characteristic in all crops. Many pathogens are specific to particular crops, and the economic importance of different pathogens often varies with geographical region. Researching genes that provide mechanisms for disease resistance should become a high priority for the Canadian Crop Genomics Initiative.

Seed quality is a major component of all cereals, pulses, and oilseed crops. The genes that control seed development, carbon partitioning, protein quality, oil quality, starch quality, and the accumulation of non-nutritional compounds will be major targets for discovery and modification by the Canadian Crop Genomics Initiative.

Resistance to insects is important for reducing crop losses and pesticide use. Canada's major crops are affected by a variety of insects, such as flea beetles in canola and wheat midge. Molecular biologists and entomologists will examine and develop a molecular basis for both antibiotic and anti-xenotic approaches to insect resistance. Germplasm and varieties will be developed with resistance to economically important insects[37].

A Human Resources component of federal climate change funding has been developed to encourage industry involvement in research and development to address applied climate change research issues as identified in the Agriculture and Agri-Food Climate Change Table

[37] http://res2.agr.ca/research-recherche/science/investin/geno-e.html#some

Options Paper. Provide matching funding for up to $250,000 per project to industry, to encourage them to partner with private, university and/or government experts in addressing climate change related issues.

13 Soils Carbon Sequestration

13.1 Soil Carbon Sequestration

Every time a plant sprouts and grows to maturity, it absorbs CO_2 from the atmosphere, breaks it down chemically and uses carbon as construction material for roots, stem, branches, flowers and leaves. When the plant dies, some of the carbon goes back into the atmosphere, but some is also released into the soil as the dead plant decays. Globally, soil contains about five times as much carbon as vegetation.

Soil carbon sequestration is widely researched, difficult to document, prone to variables and not recognised yet as a sink by the SBSTA. Despite all this, it holds enormous potential both as a carbon sink, and as an incentive to improve soil quality. Prairie soils, with 137 million acres of agricultural land, represent a large land area for enhancing Canada's carbon absorption capacity. It is estimated that carbon sinks could, on average, elevate their carbon content 2.5 to 4 tonnes per hectare over a 12-year period. SCS could become a value-added product if marketed as quantifiable emission credit. The official action plan of Canada includes SCS as an aspect of sustainable agriculture.

The European negotiation team[38] has taken a stance, which accepts that under the Kyoto Protocol "additional human-induced activities" related to changes in greenhouse gas emissions in agricultural soils, land-use change and forestry may count towards Kyoto targets. However, the Council recommends that these additional sources and sinks should not be included until after the first commitment period of 2008-2012.

The Subsidiary Body for Scientific and Technological Advice (SBSTA) convened in June 2000 and did not issue any decisions regarding agricultural soil sequestration. The negotiations will continue in November. However, good practice guidelines were issued, which clarified livestock population characterisation, and calculating emissions for livestock, manure management, and soils. The activity coefficients provided favour cattle and buffalo grazing on large areas compared to those confined to a stall, for example. Therefore, stakeholders that want to improve Canada's emissions calculations could encourage cattle producers to keep their herds on pasture.

A scientifically credible and cost-effective way of measuring, monitoring and verifying carbon changes in soils is in development. Currently, world scientists can combine data on soil carbon with landscape and climate to create models that estimate the carbon change related to farm management practices with a fair degree of accuracy

[38] from Weathervane

Suitable measures to enhance and maintain the carbon sink capacity of soils on the Prairies include:

- Minimising the acreage of tilled summerfallow and moving to longer crop rotations
- Reducing soil tillage - saving on both energy consumption and soil organic degradation
- Improving new crop varieties and yields - thereby increasing the absorption of CO_2 in the soil
- Increasing the amount of Prairie cropland returned to forage crops, which provides continuous soil cover and increases soil carbon
- Increasing energy efficiencies for all types of agricultural practices
- Using legumes and/or grasses in crop rotations
- Converting marginal cropland to perennial grass or trees
- Using rotational grazing and high-intensity/short-duration grazing
- Planting shrubs and trees as shelterbelts
- Restoring wetlands.

In humid areas, management techniques for increasing soil carbon include:

- conservation tillage
- mulch farming
- agroforestry
- cover crops

13.2 Agroforestry and Shelterbelts

Rhonda Lindenbach recently defended a master's thesis at the University of Saskatchewan that investigated whether agroforestry could increase producer returns. Her results showed negative net hectare revenues for the rotation, or a loss of approximately $9.93 per hectare. In order for agroforestry to become economically feasible under current conditions, model results indicate that a tree rotation must alter certain input cost structures. Currently, the cost of inputs such as harvesting is too high, resulting in negative net hectare revenues[39]. Lindenbach is optimistic that research and development could reveal methods that reduce inputs and improve the prospects for agroforestry in Saskatchewan. She also notes that policy changes, such as taxing fossil fuel use, could drive agroforestry into production. Lindenbach constructed simulation scenarios where grain transportation costs increased, a payment for sequestered carbon was introduced, and a climate under global warming conditions was mimicked. Under all three simulations, agroforestry net hectare revenues increased, and in some scenarios, became positive (Lindenbach, 2000).

The Native Fruit Development Program, led by Robert St. Pierre at the University of Saskatchewan, is a program of industry development oriented to the biology, culture and improvement of native fruit species. The primary goal of the program is to contribute to agricultural diversification within the province by developing some of native fruit species into new horticultural crops. Trials at the PFRA Centre at Indian Head have indicated that the mean yield of the top five commercially used cultivators (Smoky, Northline, Honeywood,

[39] From Rhonda Lindenbach's (unpublished) thesis, page 116

Martin and Thiessen) is at 9 100 lbs/acre. The possibility of adding value to shelterbelts with fruiting bushes may encourage producers to convert their marginal lands.

The Semi-Arid Centre in Swift Current has concluded that unless best management practices (e.g., proper fertilisation and adequate mixture of crops in a crop rotation) are used in conjunction with conservation tillage, the sequestration benefits of these tillage systems will not be realised.

14 GHG Emissions

Environment Canada maintains a National Greenhouse Gas Inventory that has been structured to match the "good practice" requirements of the International Panel on Climate Change (IPCC). It has been divided into six major sectors: Energy; Industrial Processes; Solvents and Other Products; Agriculture; Land Use Change and Forestry; and Waste. The accounting is then further divided into more manageable areas (ex: science, policy, implementation) and subdivided into categories (ex: transportation, agriculture, buildings).

> **For GHG inventory purposes, agriculture emissions are limited to enteric fermentation of domestic animals, manure management practices, and cropping practices that result in a release from soils.**

While this method minimises duplication, the arbitrary boundaries distort reality. The agriculture industry in the "real world" involves many aspects including land, machinery, chemicals, and transportation. Another more comprehensive approach is to account for all significant emissions related to a project, whether they take place on-site or off-site. In energy analysis, this approach is known as the total fuel cycle or *full energy supply cycle.* Under such " whole system" accounting, the material impacts of activities that relate to the project activity but occur before or after it are taken into account.

While emission reductions must be within the context of the "good practice guidelines" in order to be recognised under the Kyoto Protocol, the more comprehensive methods must be employed within national emission reduction plans in order for them to be effective. Reduction projects must consider:

Net GHG Impact: Estimating the net GHG impact of any project requires careful evaluation of both the positive and negative GHG impacts. For example, an agricultural productivity project has the objective of increasing unit agricultural production. As a result, the project may reduce the pressure on other land use forms (particularly forests) and thereby preserve an existing GHG sink. However, in some cases, the higher productivity may result in an increase in GHG emissions from the agricultural activities due to methane emission from higher yielding varieties or higher use of energy and fertilisers.

Time Frames: Determining the appropriate time frame for GHG accounting can be particularly difficult for any project involving CO_2 flux (i.e., emissions or uptake), because CO_2 fluxes are not constant and carbon sequestration may not be permanent. An individual

tree will grow (and sequester carbon) over varying rates during its life span, and growth can continue for many decades. However, once that tree is harvested, and is burned or allowed to decay, the carbon that has been sequestered will be released back to the atmosphere as CO_2. Therefore, the time frame chosen for determining project GHG impacts can have a significant effect on the result.

Global Warming Potential: To compare the climate change impacts of various gases, the scientific community has developed the concept of Global Warming Potential (GWP), which allows expression of all GHGs on a comparable basis. The strength of all other GHGs is compared to that of carbon dioxide, which is assigned a value of 1. Methane is assumed to be 21 times more powerful than CO_2 in trapping heat, while N2O is assumed to be 310 times more powerful.

Gases	Chemical Formula	20 Year Time Horizon	100 Year Time Horizon
Carbon Dioxide	CO_2	1	1
Methane	CH_4	56	21
Nitrous Oxide	N_2O	280	310

Table 1: Recent GWPs for the 3 major gases

Economic Considerations: In order for environmental concerns like climate change to be addressed, they must be "translated" into economic terms, the basis of all policy decisions. A Canadian System of environmental and resource accounts has been developed to organise physical and monetary statistics related to the environment using classifications, concepts and methods that compatible with Canadian System of National Accounts[40]. The stocks of natural resources, and changes in these stocks due to extraction, discoveries or natural growth, are shown both in physical quantities and in monetary value.

Whole system accounting is necessary for every aspect of emission reduction. Any single option can affect production and emissions in sectors other than the one covered by any particular table. While emissions accounting limits the agriculture sector to processes on the land and emissions from farm animals, changes to agricultural practices may have far-reaching effects. For example, if large amounts of land under cultivation are converted to permanent cover, this will affect the emissions resulting from the transport of grain.

Whole-economy analysis takes this a step further, and requires that options be embedded within a model of the North American or global economy, so that import and export quantities, the costs of technologies and other factors not determined solely within Canada are taken into account. While the share of products manufactured for export has increased, Canada continues to rely heavily on the export of energy-intensive natural resources, including agricultural products, and GHG emissions associated with these exports are attributed to Canadian sources.

[40] the source of many of Statistic Canada's economic statistics.

Total emissions, which were 64 Mt CO_2 equivalent in 1997, did not vary by more than 5% over the period. Of interest is the shift, over time, in the make-up of emissions from Agriculture. Carbon dioxide has declined by approximately 8 Mt, while nitrous oxide has increased by virtually the same amount (about 7 Mt CO_2 equivalent). This has occurred primarily as result of changing soil-management and fertiliser-application practices.

14.1 Methane

Ruminant animals produce methane. Ruminant animals (e.g., cattle, buffalo, sheep, and goats) are the major emitters of anthropogenic methane because of their unique digestive system. Nonruminant domestic animals like pigs and horses also produce anthropogenic methane emissions through enteric fermentation, although this microbial fermentation occurs in the large intestine. Methane emissions from enteric fermentation were 18 Mt CO_2 in 1996 and have increased 14% since 1990 due to increased beef production.

Manure management practices affect the production of methane. When livestock and poultry manure is stored or treated in systems that promote anaerobic conditions (e.g., as a liquid in lagoons, ponds, tanks, or pits), the decomposition of materials in manure tends to produce methane. When manure is handled as a solid (e.g., in stacks or pits) or deposited on pastures and rangeland, it tends to decompose aerobically and produce little or no methane. A number of other factors related to how the manure is handled also affect the amount of methane produced:

- Air temperature and moisture affect the amount of methane produced because they influence the growth of the bacteria responsible for methane formation; Soil under anaerobic conditions (wetlands and rice paddies) is a source of CH_4 emissions
- Methane production generally increases with rising temperature and residency time;
- For non-liquid based manure systems, moist conditions (which are a function of rainfall and humidity) favour methane production.

Methane emissions from manure management were 4.4 Mt CO_2 equivalent 1996, up from 4 Mt CO_2 in 1990.[41]

14.2 Nitrogen

Nitrous oxide (N_2O) is produced naturally in soils through the microbial processes of nitrification and denitrification. A number of agricultural activities add nitrogen to soils, thereby increasing the amount of nitrogen available for nitrification and denitrification, and ultimately the amount of N_2O emitted. Nitrous oxide emissions can be divided into two broad emission types: direct and indirect.

Direct additions occur through various soil management practices, including application of:

- synthetic and organic fertilisers
- sewage sludge

[41] Canada's Greenhouse Gas Inventory: 1997 Emissions and removals with trends. pp 47-8.

- animal wastes
- production of nitrogen-fixing crops
- crop residues

N_2O can also be directly applied during animal grazing, through direct deposition of animal wastes on pastures, range, and paddocks.

N_2O that is transported from the agricultural field will provide additional (indirect) nitrogen for subsequent nitrification and denitrification reactions that will produce nitrous oxide. Some of the nitrogen that is applied to agricultural fields is transported off site by volatilisation and subsequent redeposition, leaching and runoff. Other agricultural soil management practices, such as irrigation, drainage, tillage practices, and fallowing of land, can affect fluxes of N_2O, as well as other GHGs, to and from soils. However, because there are significant uncertainties associated with these other fluxes, they have not been estimated.

N_2O is also emitted as a result of cultivating organic soils (histosols), due to the high organic matter content. The IPCC default methodology has been used to estimate emissions from this source. In Canada there are over 111 million hectares of peatlands.

While Alberta is gaining 2.5 Tg yr. (-1), Saskatchewan (which has the most cultivated area) has the lowest rate of SOC gain because it has the highest area of summerfallow. Frick et al suggest that a shift of 10% of the cultivated area within each soil zone to a system incorporating increased crop frequency, the prairies could gain SOC approximately 1.9 Tg yr. (-1) faster than with 1996 land-use, for a total SOC sequestration rate of 7.7 Tg yr. (-1).

15 Research on the Prairies

Certain projects funded by Saskatchewan Agriculture and Food could be legitimately identified as having at least indirect benefits to reducing greenhouse gas emissions or to facilitating adaptation. A wide array of development projects have been funded concerning the potential for various forages and speciality crops, shelterbelts, fruiting bushes, and potential expansion of various types of livestock in accordance with the mandate to "diversify" the economy. As a public program, the results of the trials are made available in reports that producers may access. Biological pest control experiments have been funded, as have efforts to minimise fertiliser and pesticide use. This demonstrates that the program can help rehabilitate regional biodiversity, so long as this progress is not outweighed by support for ILO expansions. Greenhouse gas emissions are also reduced by production efficiencies such as:

- genetics - improved crop varieties (less fuel, fertiliser etc inputs per unit of output);
- soil conservation - maintaining soil carbon, plant nutrients;
- feed efficiencies - higher digestibility means less methane released;
- manure management - lower methane release;
- crop residue management - returning straw and stubble to the soil;
- fertiliser placement - more efficient use of nitrogen etc;

- land use changes - more land in forages, including alfalfa (legume);
- lower input use;
- crop diversification - more acres in pulse crops fix their own nitrogen).

15.1 Soils

15.1.1 Brandon

Beckie, H.J.; Moulin, A.P.; Pennock, D.J. 1997. Strategies for variable rate nitrogen fertilisation in hummocky terrain. Can. J. Soil Sci. 77:589-595.

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15.1.2 Lethbridge

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15.1.4 Alberta matched funding

- 94-0532.RES: Nitrous Oxide Emissions Under Annual Crops: Estimations of Potential Losses of Nitrogen
- 96M949.RES: Geographic Management of Fertiliser Application for Precision Farming
- 95M749.RES: Increasing the Efficiency of Polymer-Coated Nitrogen Fertilisers
- 980911.res: Crop Productivity and Soil Carbon, Nitrogen and Phosphorus Under Different Rotations at the Breton Plots
- 980914.res: Landscape Position Effects on Crop Productivity and on Carbon, Nitrogen and Phosphorus in Gray Luvisols
- 2000M675.RES: Processes of N2O Production in Agricultural Soils
- 990007.RES: Conservation of Nitrogen During Composting
- 99R002.RES: Assessing the Nitrous Oxide Tradeoffs to Carbon Sequestering Management Practices
- 98M233.res: Native Plant Species Establishment for Resource Conservation
- 980887.res: Soil and Crop Residue Management Effects on Nitrogen Cycling, Soil, and Crop Yield Response94-0533.

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Dissolved organic nitrogen in freshwater: Analysis by high temperature oxidation (S. Schiff, R. Aravena, R. Hecky) Waterloo

15.2 Livestock

15.2.1 Lethbridge

Mathison, G.W.; Okine, E.K.; McAllister, T.A.; Dong, Y. al. 1998. Reducing methane emissions from ruminants. J. Applied. Animal Res. 14:1-28.

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15.2.2 Brandon

The Brandon Research Centre has gathered information on methane production of beef cattle under range (or pasture) conditions. They concluded that cows grazing alfalfa-grass pastures consumed more dry matter, produced less methane, and lost less energy through methane release. The findings confirm that pasture type has an effect on methane production and feed efficiency. Related research completed by the Centre indicates that pasture finishing of beef cattle is feasible.

McCaughey, W.P.; Wittenberg, K.; Corrigan, D. 1997. Methane production by steers on pasture. Can. J. Animal. Science. 77:519-524.

16 Research in Canada

16.1 Soils

16.1.1 Selected Manure Projects in Canada

Hazardous manure gases (N. Patni, S. Clarke)
Agency: AAFC
Funding: AAFC, Pork Industry Improvement Plan

Sustainable Use of Livestock and Municipal Biosolids in Field Crop Production on Coarse-Textured Soils (E. Topp)
Agency: AAFC

Identification of environmental issues confronting the Saskatchewan Pork Industry (J. Morris)
Funding: ADF,

Maximising the economic and environmental benefit of land application of animal manure
Agency: University of Saskatchewan
Funding: SAF

Agronomic and Economic Assessment of Variable Rate Fertilisation (D. Anderson)
Funding: Sask. Agriculture & Food

16.1.2 University of Guelph

Prediction of available N from soil organic matter and residual legume crop N (B. Kay)

16.1.3 Alberta matching funding initiatives

- Carbon Sequestration and Soil Quality as Influenced by Tillage and Crop Rotation
- Identifying Agricultural Sources and Sinks for Atmospheric Carbon at the Landscape Level
- Quantifying Net Carbon Balance to Evaluate Cropping Practices Which Promote Soil Organic Matter Sustainability
- Stabilisation of Soil Organic Carbon

16.1.4 Sainte-Foy

Carbon

Fortin, M.-C.; Rochette, P.; Pattey, E. 1996. Soil CO2 fluxes on conventional and no-tillage systems. Soil Science. Soc. Am. J. 60:1541-1547.

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16.1.5 Matched Funding, Resource Conservation Abstracts (Alberta)

- Agricultural Effect on Primary Production and Soils of Major Prairie Ecosystems
- Earthworms: Residue and Disease Managers Under No-Till
- Cropping and Management Strategies to Promote Efficient Internal Recycling of Nutrients
- Greater Efficiency of Phosphorus Fertilisers by Coating Phosphate Granules with Polymers
- Native Plant Species for Resource Conservation
- Effectiveness of Legumes in Grass-Legume Mixtures in Reducing Fertiliser N Input for Optimum Forage Yield

16.1.6 Current Studies NSERC

Inter-annual variation in CO2 flux at boreal peatland and subarctic forest sites (P. Lafleur). Trent

Carbon sequestration, chemical denudation and fluvial geochemistry of the Cordillera - the river signal (K. Telmer). Victoria

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- Annual carbon accumulations in agroforestry plantations

16.1.9 Canadian Agrifood Research Council

- Greenhouse gas emissions from agricultural soils.
- Annual carbon accumulations in agroforestry plantations
- Cycling of carbon and nitrogen in prairie agroecosystems
- Extraction, fractionation and reactions of lipids using supercritical CO2.
- Extracting Aromas and Flavours using Supercritical Carbon Dioxide
- Managing Soil Carbon and Nitrogen Resources for Sustainable Crop Production
- Nutrient, water and carbon modelling in lowbush blueberry production
- Greenhouse gas emissions, removal of air pollutants and nitrate leaching in management systems designed for carbon sequestration
- Identifying Agricultural Sources and Sinks for Atmospheric Carbon at the Landscape Level
- Airborne flux measurements of CO_2 and moisture and trace gases.
- Annual carbon accumulations in agroforestry plantations
- Coupled climate-carbon cycle modelling (D. Harvey).

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- Kinetics of denitrification
- Evaluation of best management practices for increasing nitrogen use efficiency on farms
- Elucidating the Mechanisms Implied in the Partitioning of Nitrogen and Carbon in Dinitrogen-Fixing R
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Forages

- Genetic improvement of perennial forage and turfgrass species
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- Perennial forage crop studies
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16.2.2 Canadian Agri-Food Research Council

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- Optimising pasture management in Québec cow-calf systems: production and economic relationships
- Methane determinations for free ranging cattle - I

- Methane determinations for free ranging cattle – II
- Practical strategies to reduce methane production and emission in cattle in Alberta

16.2.3 Livestock Environmental Initiative

Livestock

- Effects of type of finishing diets on invitro lipogenesis and organoleptic qualities of beef
- Glucose transporter gene expression bovine gastrointestinal tract
- Hormones influenced by intestinal nutrient-gene interactions
- Alternate day roughage feeding schedules for wintering beef cows
- Different barley varieties with different rates of starch degradation influence ruminal fermentation
- Biodiesel canola meal: a new feed resource for lambs that may prevent global warming

Forages

- Carbon and nitrogen flows through rotational pasture swards

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17 International Research

It seems that a universal area of concern is a need for a constant flow of reliable data. The uncertainty associated with emissions from the agriculture sector, for example, is thought to be between 20 and 80%. New data sources are continually sought to allow verification of existing data.

The Energy Department report, *Emission and Reduction of Greenhouse Gases from Agriculture and Food Manufacturing*, is the first comprehensive analysis of U.S. agricultural activities and their impact on greenhouse gas emissions. The report finds that agricultural and forestry industries currently produce one-tenth of all greenhouse gases emitted in the

United States. The greatest impact of those emissions comes from methane and nitrous oxide rather than carbon dioxide.

The report also provides strong support for accelerating the development of bio-based products industry to satisfy a portion of that increased demand. An integrated bioenergy industry will boost opportunities for rural America, reduce greenhouse gas emissions, lower dependence on oil imports and expand the possibilities for sustainable energy use in power production, transportation, agriculture, chemicals and manufacturing[42].

A report released in January 2000 by the U.S. Department of Energy (DOE) concludes that by the year 2010, the agriculture and forestry industries could help reduce greenhouse gas emissions by producing and utilising more bio-based products, fuels and power. (Bioenergy comes from natural resources such as corn, trees, crops, agricultural, forest and aquatic resources to make an array of commercial products, including fuels, electricity, chemicals, adhesives, lubricants and building materials.)

Research and extension activities are also addressing more effective fertiliser extension of minimum tillage practices and stubble retention as an alternative to burning agricultural residues in the field. Such activities have potential benefits for agricultural efficiency and land management beyond the likely greenhouse benefits.

Australia's National Greenhouse Strategy, an initiative released in 1998, contains measures that target the reduction of greenhouse gas emissions from the agriculture sector. Governments are also promoting the delivery of programs addressing sustainable agricultural management practices, including:

- Conservation cropping
- Opportunities to improve animal husbandry
- Manure management
- The use of biogas and other technologies by intensive animal industries
- Reduction of biomass burning

The Australian Greenhouse Office is currently developing proposals for the Greenhouse Gas Abatement Program to be supported from the *New Tax System* package from July 2000. This program will emphasise activities that are expected to achieve maximum emissions reductions[43].

Australia is undertaking extension programs conducted by government agriculture departments to help farmers achieve increase deficiency. The programs specifically target rangeland systems and animal waste processing systems for intensive livestock holdings. In the area of research, the Government has funded CSIRO to further develop its methanogen vaccine, which is suitable for sheep and cattle, and has the potential to reduce methane emissions and increase production.

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[42] http://www.doe.gov/news/releases00/janpr/pr00007.htm
[43] http://www.greenhouse.gov.au/inventory/pdfs/fs_agriculture.pdf

18 Definitions

abatement is the reduction of the degree or intensity of emissions.

activities implemented jointly -- see *Joint Implementation.*

adaptability refers to the degree to which adjustments are possible in practices, processes, or structures of systems to projected or actual changes of climate. Adaptation can be spontaneous or planned, and be carried out in response to or in anticipation of changes in conditions.

Annex I parties, or ANNEX B PARTIES, in climate change negotiations refer to industrialised countries that are trying to return their greenhouse gas emissions to 1990 levels by the year 2000 as per Article 4.2 of The Kyoto Protocol.

allocation is the division of emissions permits or allowances among greenhouse gas emitters for the purpose of establishing a market in tradable permits. There are several possible methods for allocating permits, including grandfathering and permit auctioning.

assigned amounts are binding emissions reductions commitments agreed upon by Annex B countries in The Kyoto Protocol that are based on 1990 baseline emissions.

banking entails saving emissions permits or Certified Emissions Reductions for future use in anticipation that these will accrue value over time.

benefit-cost analysis is an economic technique applied to public decision making that attempts to quantify in dollar terms the advantages (benefits) and disadvantages (costs) associated with a particular policy. For example, a policy that requires a power plant near the Grand Canyon to install pollution abatement equipment would reduce air emissions from the plant and improve the visibility at the Grand Canyon for visitors (a benefit), but would increase the cost of electricity to customers (a cost).

binding targets refer to environmental standards that are to be met in the future.

bubble refers to the idea that emissions reductions anywhere within a specific area count toward compliance. For example, if a plant with multiple emissions sources is treated as being "under an emissions bubble," regulators assess only the total emissions of the plant, not the emissions of each individual source, in determining compliance.
carbon sequestration generally refers to capturing carbon -- in a carbon sink, such as the oceans, or a terrestrial sink such as forests or soils -- so as to keep the carbon out of the atmosphere.
For further reading on carbon sequestration, see *Carbon Sinks in the Post-Kyoto World*, by Roger A. Sedjo. Brent Sohngen, and Pamela Jagger.

carbon sink -- see *carbon sequestration*.

carbon taxes discourage the use of fossil fuels and aim to reduce carbon dioxide emissions by placing a surcharge on the carbon content of oil, coal, and gas.

Certified Emission Reductions (CERs) or Certified Emission Reduction Units (CERUs) are verified and authenticated units of greenhouse gas reductions from abatement or sequestration projects which are certified by the Clean Development Mechanism.

Clean Development Mechanism (CDM) is a modified version of Joint Implementation that was included in The Kyoto Protocol for project-based activities in developing countries. In Article 12.2 of the Protocol, the parties established the CDM for the purposes of assisting developing countries in achieving sustainable development and helping Annex I parties meet their emissions limitation and reduction obligations. Under the supervision of an executive board, private and public funds may be channelled through this mechanism to finance projects in developing countries. One innovative aspect is that a share of the proceeds from project activities is to be used to cover the administrative expenses of the clean development mechanism . Another part of those proceeds will be used to help particularly vulnerable developing countries meet the costs of adapting to a changing climate. As the Protocol stands now, developing country commitments are restricted to voluntary participation in CDM and the undertaking of general obligations such as the formulation of national programs and political as well as scientific co-operation among each other.
For further reading on the CDM, see *The Clean Development Mechanism: A Primer*, by Michael Toman and Marina Cazorla.

climate change can be caused by an increase in the atmospheric concentration of greenhouse gases which inhibits the transmission of some of the sun's energy from the earth's surface to outer space. These gases include carbon dioxide, water vapour, methane, chlorofluorocarbons (CFCs), and other chemicals. The increased concentrations of greenhouse gases result in part from human activity -- deforestation; the burning of fossil fuels such as gasoline, oil, coal and natural gas; and the release of CFCs from refrigerators, air conditioners, etc.

command-and-control regulation requires polluters to meet specific emission-reduction targets and often requires the installation and use of specific types of equipment to reduce emissions.

commitment periods are a range of years within which parties to The Kyoto Protocol are required to meet their GHG emissions reduction target, which is averaged over the years of the commitment period. The first commitment period will be 2008-2012.

Conference of Parties (COP) is the supreme body of the UN Framework Convention on Climate Change. It comprise 170+ nations that have ratified the Convention. Its first session was held in Berlin, Germany, in 1995, and is expected to continue meeting on a yearly basis. The COP's role is to promote and review the implementation of the Convention. It will periodically review existing commitments in light of the Convention's

objective, new scientific findings, and the effectiveness of national climate change programs.

developing countries, or *less developed countries (LDCs)*, are those countries that are in the process of becoming industrialised but have constrained resources with which to combat their environmental problems.

double dividend refers to the notion that environmental taxes can both reduce pollution (the first dividend) and reduce the overall economic costs associated with the tax system by using the revenue generated to displace other taxes that slow economic grow at the same time (the second dividend).

downstream refers to any point in the economy, and in particular, at the level of energy consumers rather than suppliers. It is commonly interpreted to be industrial boilers, electric utilities and other major energy users, but also applies, in theory, to all consumers of gasoline, coal, electricity etc.

ecosystem is the complex of plant, animal, fungal, and microorganism communities and their associated non-living environment interacting as an ecological unit. Ecosystems have no fixed boundaries; instead, their parameters are set according to the scientific, management, or policy question being examined. Depending upon the purpose of analysis, a single lake, a watershed, or an entire region could be considered an ecosystem.

emissions are pollutants released into the air or waterways from industrial processes, households or transportation vehicles. *Air emissions* pertain to atmospheric air pollution; *water emissions* refer to pollutants released into waterways.

emission taxes are taxes levied on air or water emissions, usually on a per ton basis. Emission taxes provide incentives for firms and households to reduce their emissions and therefore are a means by which pollution can be controlled. The greater the level of the emissions tax, the greater the incentive to reduce emissions.

emissions trading is an economic incentive-based alternative to command-and-control regulation. In an emissions trading program, sources of a particular pollutant (most often an air pollutant) are given permits to release a specified number of tons of the pollutant. The government issues only a limited number of permits consistent with the desired level of emissions. The owners of the permits may keep them and release the pollutants, or reduce their emissions and sell the permits. The fact that the permits have value as an item to be sold or traded gives the owner an incentive to reduce their emissions.

energy security is a term used to describe a variety of issues from the economic cost of oil supply disruptions to the cost of military expenditures to secure international trade.

evapotranspiration is the loss of water from the soil both by evaporation and by transpiration from the plants growing in the soil and rises with air temperature

externalities occur when the activity of one person has an inadvertent impact on the well being of another person. Many aspects of environmental degradation, such as air pollution, global warming, loss of wilderness, and contamination of water bodies, are viewed as externalities of economic transactions.

flexibility mechanisms as established by The Kyoto Protocol seek to increase the flexibility and reduce the costs of making emissions reductions; the three primary mechanisms contained within the Protocol are the Clean Development Mechanism, emissions trading, and Joint Implementation (or activities implemented jointly).

fossil fuels include coal, petroleum and natural gas.

fuel cycle refers to the total life of a fuel in all its uses and forms. For example, the fuel cycle of coal is extraction; transportation; combustion; air emissions, and ash removal, transportation and disposal.

general circulation models are complex computer simulations of climate and its various components used by researchers and policy analysts to predict climate change. Typically run on "super computers," these models can approximate future climates and give some clues to how climate has changed or might change over time.

geographic information systems (GIS) are organised collections of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information. GIS is being used by many researchers in the environmental field to view a number of different indicators simultaneously as data layers on a geographic grid. By associating data of all kinds with points on a map, GIS can illustrate patterns and trends that might otherwise be incomprehensive. For example, using GIS, a researcher can map multiple health indicators at and around a specific toxic waste site.

global warming is the progressive gradual rise of the earth's surface temperature thought to be caused by the greenhouse effect and responsible for changes in global climate patterns.

Global Warming Potentials (GWPs) are an index created in The Kyoto Protocol that allows for equal comparison of the various greenhouse gases due their varying power to accelerate global warming and/or the duration of their presence in the atmosphere.

grandfathering of emissions permits is a method by which permits for greenhouse gas emissions may be allocated among emitters and firms in a domestic emissions trading regime according to their historical emissions. Supporters of this method of emissions trading assert that this would be administratively simple but some critics argue that this method would reward firms with high historical emissions and unfairly complicate entry into markets by new firms and emitters.

greenhouse effect is the progressive, gradual warming of the earth's atmospheric temperature, caused by the insulating effect of carbon dioxide and other greenhouse gases that have proportionately increased in the atmosphere. The greenhouse effect disturbs the way the Earth's climate maintains the balance between incoming and outgoing energy by allowing short-wave radiation from the sun to penetrate through to warm the earth, but preventing the resulting long-wave radiation from escaping back into the atmosphere.

greenhouse gases include the common gases of carbon dioxide and water vapour, but also rarer gases such as methane and chlorofluorocarbons (CFCs) whose properties relate to the transmission or reflection of different types of radiation. The increase in such gases in the atmosphere, which contributes to global warming, is a result of the burning of fossil fuels, the emission of pollutants into the atmosphere, and deforestation.

hot air in recent climate change negotiations refers to reductions in greenhouse gas emissions, for example, in the former Soviet Union, due to economic collapse, as opposed to intentional efforts to curb emissions.

incentive-based regulation uses the economic behaviour of firms and households to attain desired environmental goals. Incentive-based programs involve taxes on emissions or tradable emission permits. The primary strength of incentive-based regulation is the flexibility it provides the polluter to find the least-cost way to reduce emissions.

industrialised countries are characterised by relative political stability and long-term industrial success. Their per capita income is comparable to those of Canada, Northern Europe, and the United States, and they have achieved a higher level of economic and environmental sustainability than developing countries because of higher levels of capital and natural resources.

internalising the externality is an economic concept where the polluter directly bears the cost created by his pollution.

irreversibilities refer to changes that, once set in motion, cannot be reversed, at least on human time scales.

Joint Implementation (JI), or ACTIVITIES IMPLEMENTED JOINTLY, is a concept where industrialised countries meet their obligations for reducing their greenhouse gas emissions by receiving credits for investing in emissions reductions in developing countries. Proponents of joint implementation argue that such an international trade in emissions credits would achieve greenhouse gas reductions in industrialised countries at much lower costs while providing foreign investment benefits to developing countries.

Kyoto forests refer to forests that comply with the specifications of the Kyoto Protocol. Under Article 3, carbon sequestration will be credited only for forests planted after

January 1, 1990 and only for carbon sequestered during the commitment period of 2008-2012.
targets.

nitrogen dioxide (NO2) is a form of air pollution that is a brownish gas produced when nitric oxide emitted from power plants combines with oxygen already in the atmosphere. It can damage trees and lead to acid rain, which can harm lakes and streams and also corrode exposed materials. In the presence of sunlight and volatile organic compounds, NO2 can contribute to the formation of ground-level ozone, or smog.

nitrogen oxides (NOX) are often mentioned in discussions of nitrogen-based air pollution as a reference to both nitric oxide (NO) and nitrogen dioxide (NO2). In addition to particulate and sulfur dioxide, NOX is one of the major electricity-related pollutants. It can transform to nitrates in the atmosphere (which is a fine particulate).

nonlinearities occur when changes in one variable cause a more than proportionate impact on an other variable.

OECD refers to **the Organisation for Economic Co-operation and Development**. It includes Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Korea, Japan, Luxemborg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

ozone at the ground level is a form of air pollution that is produced when nitrogen oxides and hydrocarbons react in sunlight. It is not to be confused with stratospheric ozone, which is found 9 to 18 miles high in the Earth's atmosphere and protects people from harmful radiation from the sun. Ground-level ozone pollution, or smog, is mainly a problem during hot summer days.

policy stringency is the strict adherence to policy goals and desired results by all relevant parties. An example of environmental policy stringency is typically measured as a targeted reduction in carbon dioxide emissions

polluter pays principle which states that those who cause industrial pollution should offset its effects by compensating for the damage incurred, or by taking precautionary measures to avoid creating pollution.

precautionary principle in the context of the Framework Convention on Climate Change refers to the idea that action to forestall large-scale, irreversible damage from climate change is warranted even though the risks of climate change are not yet fully understood. The precautionary principle thus puts a premium on the long-term safeguarding of the world's climate system, even in the face of uncertainty about the impacts and the need to bear near-term costs of mitigation.

renewable resources are energy sources that do not use exhaustible fuels. Sources of renewable energy include water, wind, solar energy and geothermal energy, as well as some combustible materials, such as landfill gas, biomass, and municipal solid waste.

revenue-raising instruments in environmental policy include emissions taxes, which are levied against producers of pollution; and tradable emissions permits, which can be bought or sold by coal-burning electric utilities and other industries.
revenue-recycling occurs when the revenue raised by an environmental policy is used to reduce other taxes or government deficits or is rebated to households.

satellite remote sensing is the collection of data on land use, industrial activity, weather, climate, geology and other processes through Earth observations from satellites in outer space.

sensitivity is the degree to which a system will respond to a change in climatic conditions.

sinks -- see *carbon sequestration*.

sulphur dioxide (SO2) is a form of air pollution that is a gas. It results from the combustion of fuels that contain sulphur. SO2 is most prevalent in the combustion of coal.

sustainable development is a broad concept referring to the need to balance the satisfaction of near-term interests with the protection of the interests of future generations, including their interests in a safe and healthy environment. As expressed by the 1987 UN World Commission on Environment and Development (the "Brundtland Commission"), sustainable development "...meets the needs of the present without compromising the ability of future generations to meet their needs."

tax-interaction effect can occur when environmental policies, such as emission taxes or permits, and the conventional tax system interact. This effect is the cost of the overall reduction in employment and investment caused by environmental policies, which exacerbate the effects of pre-existing taxes on labour and capital.

technology-forcing regulations are requirements and standards set by governments to catalyse environmental research and development. Some examples include corporate average fuel economy (CAFE) regulations and other energy efficiency requirements.

technology transfer in the context of climate change policy most often refers to the process by which energy-efficient technologies and processes developed by industrialised nations are made available to the less-industrialised nations. These transfers may be conducted solely through the efforts of private parties or may involve governments and international institutions.

tradable emissions permits are used in an environmental regulatory scheme where the sources of the pollutant to be regulated (most often an air pollutant) are given permits to release a specified number of tons of the pollutant. The government issues only a limited number of permits consistent with the desired level of emissions. The owners of the permits may keep them and release the pollutants, or reduce their emissions and sell the permits. The fact that the permits have value as an item to be sold gives the owner an incentive to reduce their emissions. See also *emissions trading*.

United Nations Framework Convention on Climate Change (UNFCCC) is the centrepiece of global efforts to combat global warming. It was adopted in June 1992 at the Rio Earth Summit, and entered into force on March 21, 1998. The Convention's primary objective is the "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (man-made) interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner."

upstream refers to the point (or close to it) where fossil fuels enter the economy. In the U.S., it means at the input to oil refineries, at coal processing plants and where natural gas enters pipelines

vulnerability defines the extent to which climate change may damage or harm a system. It depends not only a system's sensitivity but also on its ability to adapt to new climatic conditions